NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 503

PUMPS

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CHAPTER 503

PUMPS

SECTION 1.

SAFETY

503-1.1 SAFETY INSTRUCTIONS

503-1.1.1 GENERAL. Operation of the three types of pumps discussed in this chapter - centrifugal, rotary, and reciprocating - can be hazardous both to personnel and equipment unless specific safety measures are taken. Safety measures are referenced in this section for each type of pump; the definitive safety measures are placed in the first paragraph of each section, preceding discussion of the pumps, their characteristics, and operation.

503-1.1.2 SAFETY MEASURES FOR CENTRIFUGAL PUMPS. Safety measures for centrifugal pumps are presented in paragraph 503-2.1.

503-1.1.3 SAFETY MEASURES FOR ROTARY PUMPS. Safety measures for rotary pumps are presented in paragraph 503-3.1.

503-1.2 SAFETY MEASURES FOR RECIPROCATING PUMPS

503-1.2.1 Safety measures for reciprocating pumps are presented in paragraph 503-4.1.

SECTION 2.

CENTRIFUGAL PUMPS

503-2.1 CENTRIFUGAL PUMP SAFETY PRECAUTIONS

503-2.1.1 The following safety measures must be followed exactly to minimize hazards to personnel and equipment while operating centrifugal pumps:

a. If relief valves are fitted, ensure that they function at designated pressure.

b. Ensure that the steam valve to the turbine is closed when attempting to jack a pump by hand.

c. Boiler feed system pumps shall not be used for purposes other than those connected with boiler or feedwater service.

d. Do not tie down or otherwise render inoperative the overspeed trip, speed-limiting, or speed-regulating governor.

e. Ensure that overspeed trips, where fitted, are set to shut off steam to the unit when rated speed is exceeded by 15 percent.

f. Ensure that speed-limiting and speed-regulating governors are set to limit pump speed to rated speed under rated conditions, and that rated speed is not exceeded by more than 5 percent for any loading conditions.

g. Overspeed trip and speed-limiting governor settings shall be verified by forces afloat as authorized by NAVSEA, using validated PMS procedures.

h. When inspecting or overhauling vertical centrifugal pumps, never rely on a flexible coupling to support the total pump rotor weight. Always support the rotors with wire rope slings, block and tackle, or chocks before working on the pump. Pads or wrappings shall be used to protect the shafts or shaft sleeve areas of the supporting devices.

i. Before opening the steam end of turbine-driven pumps, ensure that drains are open and that steam and exhaust root valves are wired shut. If double valve protection is provided, wire both valves shut.

503-2.2 GENERAL DESCRIPTION

503-2.2.1 Centrifugal pumps are used for the majority of nonviscous liquid services on ships. Advantages of a centrifugal pump include simplicity, compactness, weight saving, and adaptability to the high-speed prime mover. Disadvantages are lack of suction lift (until the pump has been primed), and sensitivity to variations in head and speed.

503-2.2.2 Centrifugal pumps are usually designed for a specific set of operating conditions (design point) and may perform unsatisfactorily when subjected to conditions that vary significantly from the design point. The principles of centrifugal pump operation, suitable application, and limitations of the various types, therefore, must be understood.

503-2.3 CENTRIFUGAL PUMP TERMINOLOGY

503-2.3.1 The following terminology applies to centrifugal pumps:

a. Bearing - A bearing is a part which supports or positions the shafts on which a rotor is mounted. A bearing may be internal (bearing being lubricated by the liquid being pumped) or external (bearing isolated from the liquid being pumped). The bearings may be either an anti-friction (roller or ball bearing) or fluid film type (sleeve and journal).

b. Bearing housing - A body in which the bearing is mounted.

c. Casing - The portion of the pump which includes the impeller chamber and volute or diffuser.

d. Shaft coupling - A mechanism used to transmit power from the drive shaft to the pump shaft or to connect two pieces of shaft.

e. Diffuser - A piece, adjacent to the impeller exit, which has multiple passages of increasing area for converting velocity to pressure.

f. Impeller - The bladed member of the rotating assembly of the pump which imparts the centrifugal force to the liquid being pumped.

g. Casing wear ring - A stationary replaceable ring to protect the casing at a running fit with the impeller. Wearing rings provide an easily and economically renewable leakage joint between the impeller and the casing. Wear occurs due to the pressure differential across the leakage joint.

h. Nozzle - The portion of the pump casing between the pump and piping connection that is designed to convert fluid velocity to pressure.

i. Shaft sleeve - A cylindrical piece fitted over the shaft to protect the shaft through the stuffing box, and which may also serve to locate the impeller on the shaft.

503-2.4 CENTRIFUGAL PUMP TYPES

503-2.4.1 GENERAL. Centrifugal pumps are most commonly typed by their general mechanical configuration as follows (Figure 503-2-1):

a. Overhung Impeller Type - The impeller (or impellers) is mounted on the end of a shaft which is cantilevered or overhung from its bearing supports. These pumps are further categorized as either close coupled, where the impeller is mounted directly on the driver shaft; or separately coupled, where the impeller is mounted on a separate pump shaft supported by its own bearings.

b. Impeller Between the Bearings Type - The impeller (or impellers) is mounted on a shaft with bearings at both ends. The impeller is mounted between the bearings. These pumps are further categorized into single stage and multistage configurations.

c. Turbine Type - Pumps which are built mostly with internal, liquid lubricated bearings and diffuser casings, which are convenient for multistage construction, and which discharge through a supporting column pipe.

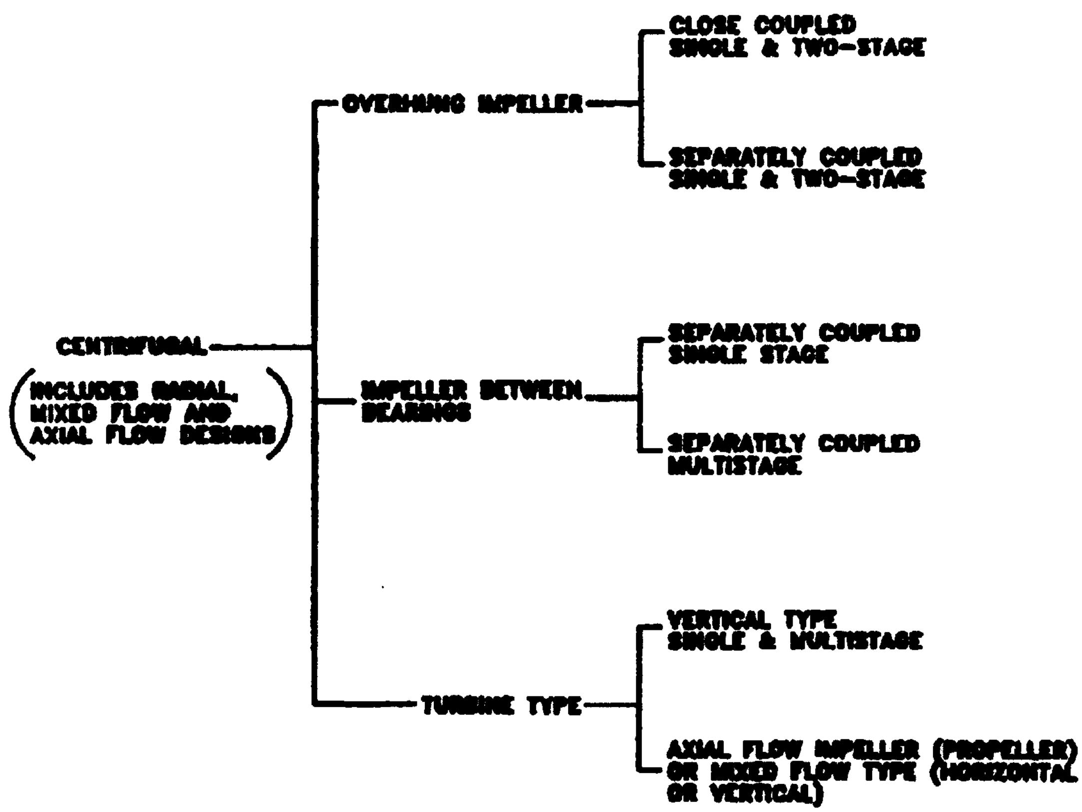


Figure 503-2-1 Centrifugal Pump Types by Mechanical Configuration

503-2.4.2 IMPELLER DESIGNS. Centrifugal pumps are also grouped by the hydraulic geometry of their impeller designs as follows (Figure 503-2-2):

a. Radial Flow - The liquid enters the impeller axially at the hub and flows radially to the periphery.

b. Mixed Flow - A single inlet impeller with the flow entering axially and discharging in an axial and radial direction.

c. Axial Flow (Propeller Pump) - A single inlet impeller with the flow entering axially and discharging nearly axially.

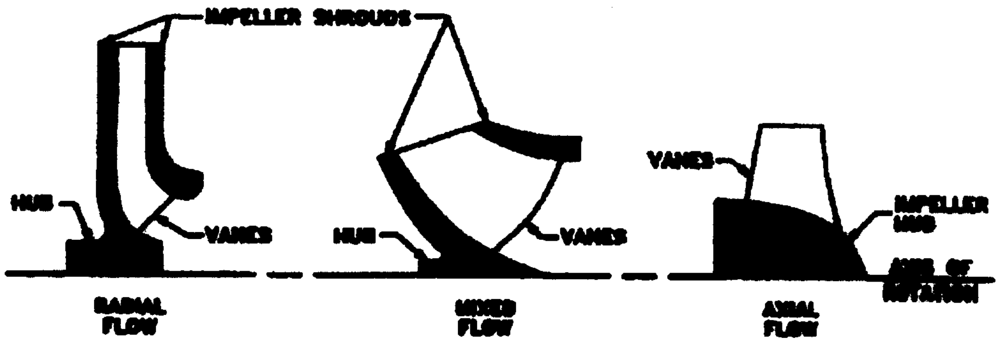


Figure 503-2-2 Hydraulic Geometry of Centrifugal Pump Impellers

503-2.4.3 COMPARISON OF IMPELLER DESIGNS. A radial flow impeller develops pressure principally by the action of centrifugal force, while an axial flow impeller develops most of its head by the propelling or lifting action of the vanes on the liquid. As the name suggests, a mixed flow impeller develops its head by a combination of centrifugal force and the lifting action of the vanes. Radial flow pumps produce low capacity at high head and axial flow pumps produce high capacity at low head.

503-2.4.4 VACUUM PUMPS. Vacuum pumps are typically of the liquid ring wet-vacuum design as shown in Figure 503-2-3. The rotor (impeller) consists of a series of blades projecting from a hollow cylindrical hub through which the shaft has been pressed. The blades are shrouded at the sides forming a series of chambers. The pump body (casing) typically has a circular shape with the rotor passing through the body eccentrically. Approximately half of the casing contains seal water and when the rotor spins, centrifugal force causes the seal water to follow the contour of the body forming a liquid ring. As the rotor spins the seal water moves in and out of the rotor chamber due to the eccentric position of the rotor in the body. The seal water acts as a liquid piston in the rotor chamber causing a positive displacement action that compresses the air in the rotor chamber. Although called vacuum pumps, these machines operate more like a compressor taking air from below atmospheric pressure, compressing it, and discharging it at atmospheric pressure.

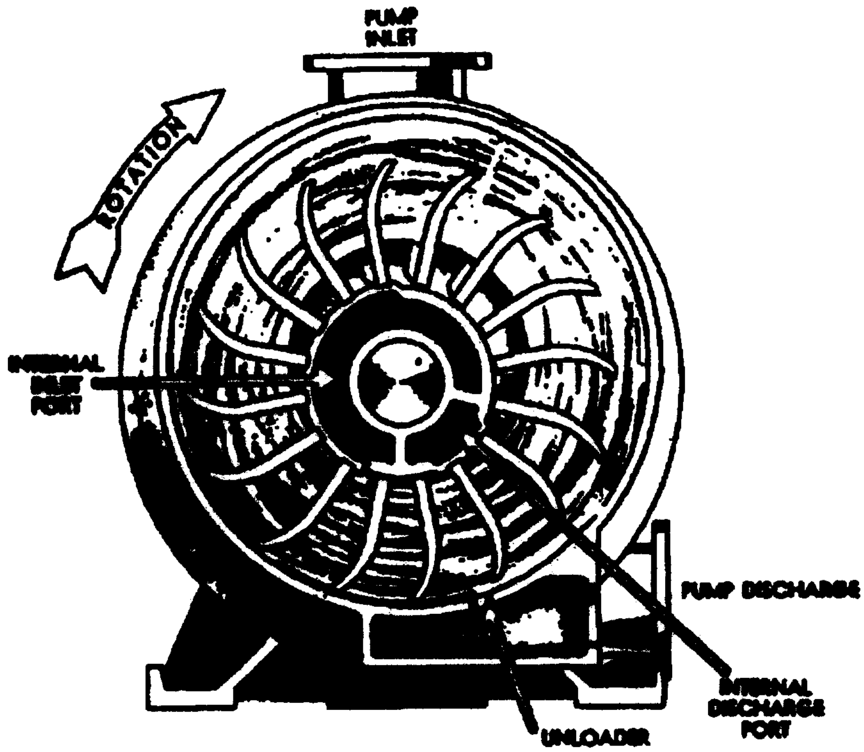
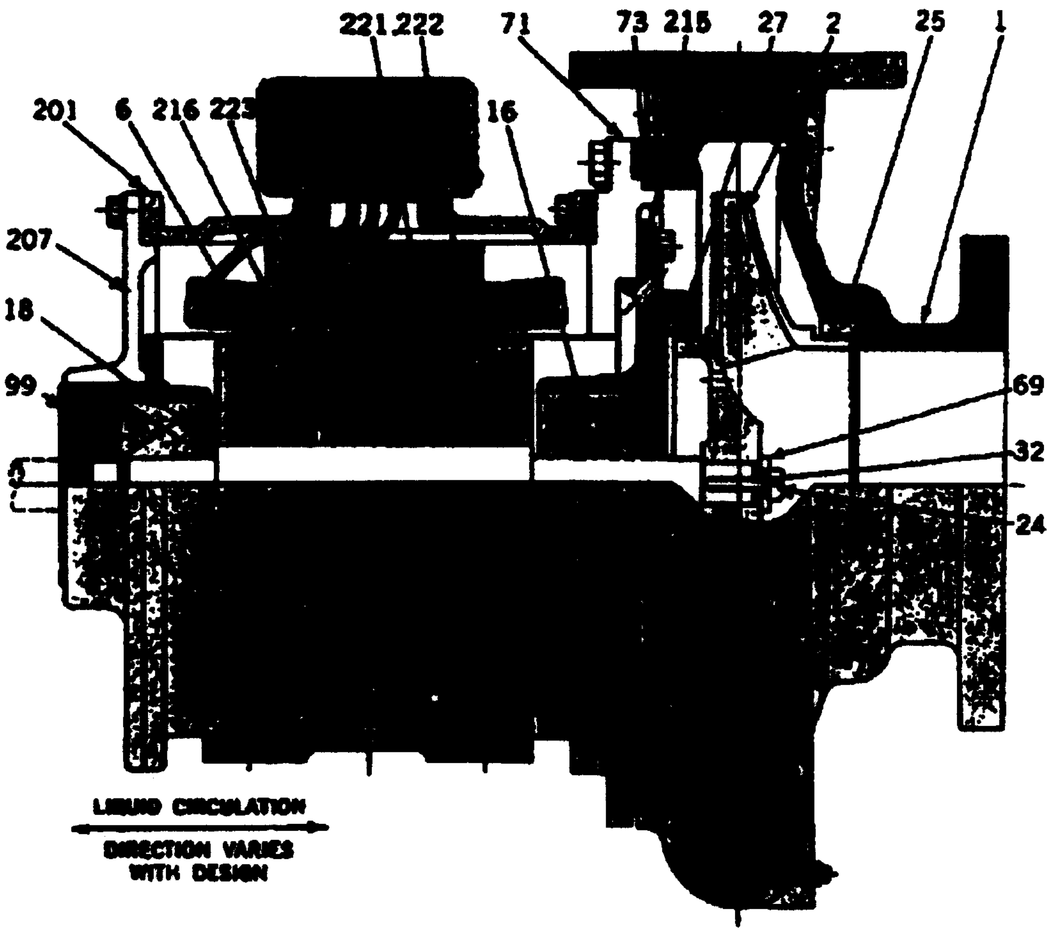


Figure 503-2-3 Liquid Ring Vacuum Pump

503-2.4.5 CANNED MOTOR PUMPS. Canned motor pumps are close-coupled pumps with the motor rotor and stator sealed in separate cans. Canned motor pumps are completely sealed to contain all pumped fluid, therefore, they do not have mechanical seals or packing. The pumped fluid is used to lubricate the bearings and cool the motor. Canned motor pumps are used where containment of the pumped fluid is essential. Refer to Figure 503-2-4 for a cross-section view of a typical canned motor pump.



1	Casing	27	Ring, Stuffing Box	207	Cover, Motor End
2	Impeller	32	Key, Impeller	215	Housing Bearing and Wearing Ring
6	Shaft, Pump	69	Lockwasher		
16	Bearing, Inboard	71	Adapter	216	Can, Stator
18	Bearing, Outboard	73	Gasket	221	Can, Rotor
24	Nut, Impeller	99	Housing, Bearing	222	Assembly, Rotor Core
25	Ring, Suction Cover	201	Housing, Stator	223	Assembly, Stator Core

Figure 503-2-4 Canned Motor Pump

503-2.5 OPERATION PRINCIPLES

503-2.5.1 The centrifugal pump imparts energy to a liquid through centrifugal force which is produced by rotating an impeller within a casing. When the liquid in the impeller is forced away from the eye (center) of the impeller, a reduced pressure is produced and consequently more liquid flows. A steady flow through the impeller is produced unless something causes the vacuum at the inlet to be broken, the flow to the impeller eye to be disrupted, or the flow at the discharge to be restricted by a pressure greater than the pressure head developed by the rotating impeller. The liquid leaves the impeller at a high velocity and is collected by a progressively expanding spiral casing (volute) where the velocity is reduced and converted to pressure head. In a diffusion pump, stationary guide vanes called diffusion vanes surround the impeller. The change of flow direction and conversion of velocity head to pressure head occurs in the diffusion vanes.

503-2.5.2 Diagrammatic sectional views of volute and diffusion centrifugal pumps are shown in Figure 503-2-5 and Figure 503-2-6.

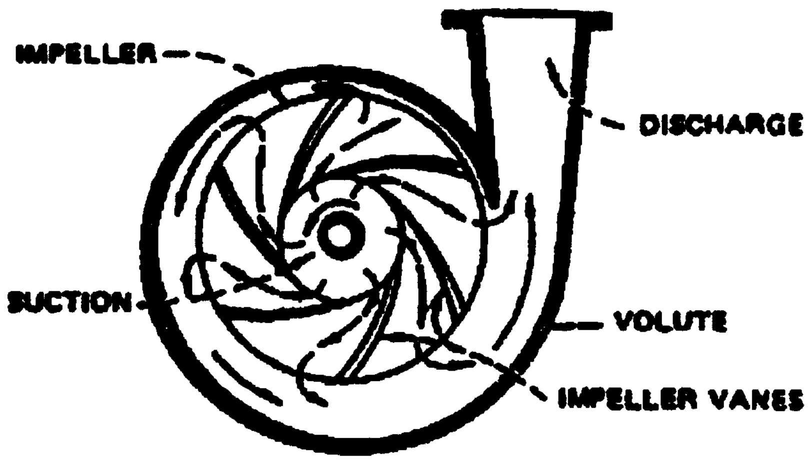


Figure 503-2-5 Volute Centrifugal Pump

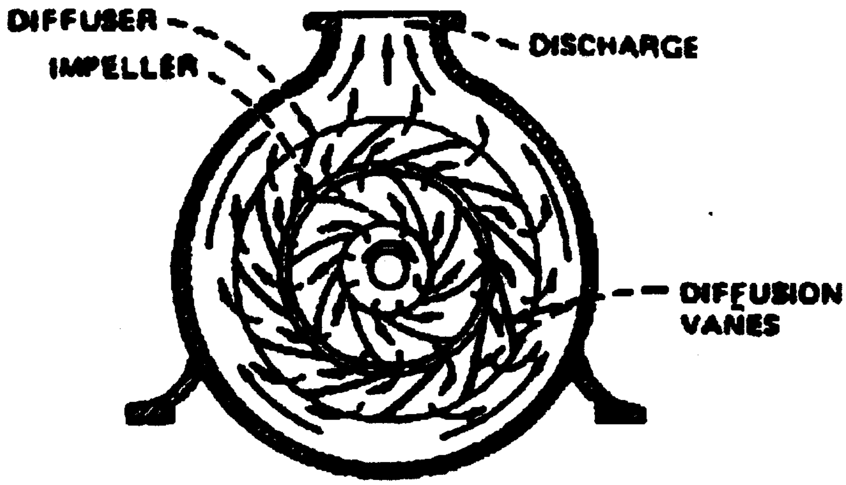


Figure 503-2-6 Diffusion Centrifugal Pump

503-2.6 CLASSIFICATION

503-2.6.1 GENERAL. Centrifugal pumps are classified in several ways, including:

a. Service application (refer to paragraph 503-2.6.2).

b. Number of stages.
   1. Single-stage.
   2. Two-stage.
   3. Multistage.

c. Shaft position.
   1. Horizontal.
   2. Vertical.
   3. Inclined.

d. Impeller type.
   1. Single suction or double suction.
   2. Open, semiclosed, or closed.
   3. Radial flow, mixed flow, or axial flow (propeller).

e. Casing type.
   1. Volute, diffuser, or turbine.
   2. Axially split, radially split, or barrel.

f. Piping connection arrangement: side, end, top, or bottom, identified to both suction and discharge connections.

g. Materials: Nodular iron, bronze-fitted, all bronze, steel, stainless steel, titanium, nickel-aluminum-bronze, copper-nickel alloy (70-30), Monel, and other special alloys.

NOTE

Cast iron and bronze-fitted pumps are seldom used in shipboard service because of shock-proofing problems and rapid corrosion when handling seawater.

h. Drive type: flexible coupled, rigid coupled, close coupled, or gear- or belt-driven.

i. Other classifications, such as special construction, direction of rotation (or reversible), and kind of power drive.

503-2.6.2 SERVICE APPLICATION. The various centrifugal pumps used in ships have requirements and operation and installation problems peculiar to each application. The more distinctive pump types are listed in this paragraph according to application. Because ship classes vary, all the services listed may not be found on every ship; also, special machinery plants may require pumps not listed. Following are the primary service applications:

a. Steam Propulsion Systems
   1. Boiler feed pumps
   2. Feed booster pumps
   3. Condensate pumps
   4. Circulating pumps

b. Fuel Systems
   1. Fuel transfer pump
   2. JP-5 transfer pump
   3. Cargo fuel pump
   4. Cargo JP-5 pump

c. Auxiliary Systems
   1. Miscellaneous circulating and supply pumps
   2. Distilling plant pumps
   3. Potable water pumps
   4. Fire pumps
   5. Portable pumps
   6. Vacuum priming pumps

503-2.6.3 GENERAL CHARACTERISTICS. Unlike positive displacement pumps, centrifugal pumps deliver a wide range of flows at relatively constant head (pressure). A centrifugal pump at constant speed will deliver liquid at any capacity from zero to a maximum capacity (determined by pump size, suction condition, and design factors). At constant speed the pressure, efficiency, and power required vary over the range of the pump capacity according to relationships that are expressed by a pump characteristic curve.

A typical pump characteristic curve is shown in Figure 503-2-7.

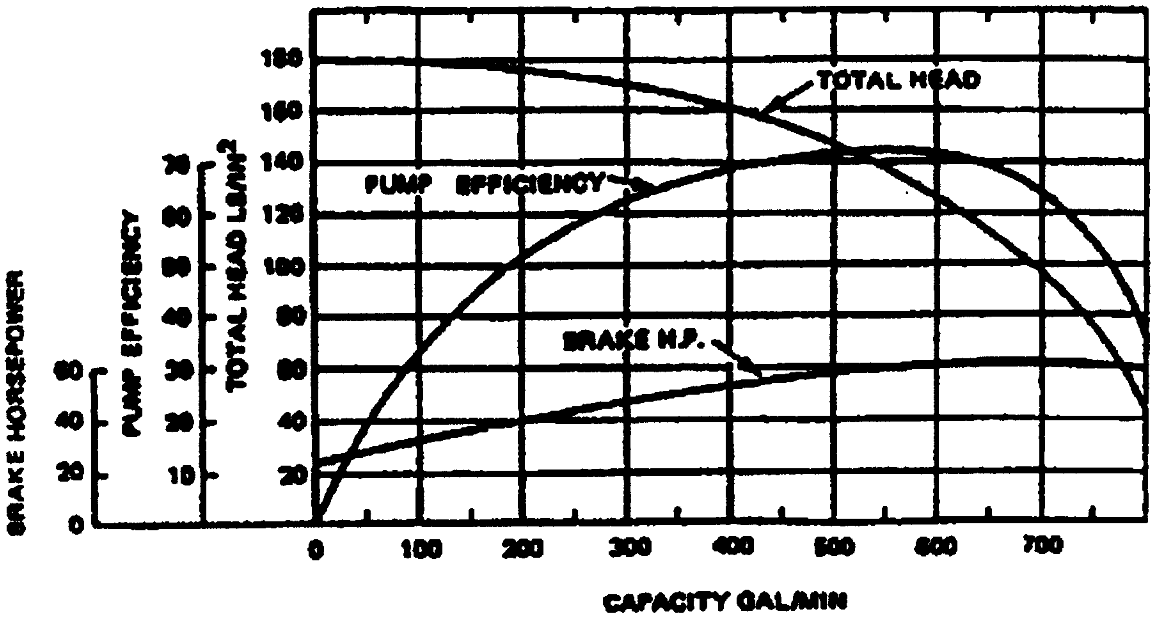


Figure 503-2-7 Typical Centrifugal Pump Characteristic Curve

503-2.6.3.1 Affinity Laws. In all centrifugal pumps the affinity laws allow you to project capacity, head, and brake horsepower for small changes in pump speed. For a given pump the affinity laws are:

a. The capacity varies directly as the speed:

b. The total head varies as the square of the speed:

c. The brake horsepower varies as the cube of the speed:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

$$\frac{H_1}{H_2} = \left[\frac{N_1}{N_2}\right]^2$$

$$\frac{BHP_1}{BHP_2} = \left[\frac{N_1}{N_2}\right]^3$$

where:

Q = capacity (gpm)

H = total head (feet)

BHP = brake horsepower

N = pump speed (rpm)

1 = initial condition

2 = final condition

503-2.6.3.2 Total Head Of Centrifugal Pump. The following formula may be found useful to determine the approximate total head a centrifugal pump will develop:

$$H = f\left[\frac{DN}{1840}\right]^2$$

where:

H = total head in feet of liquid.

D = impeller diameter in inches.

N = pump revolutions per minute.

f = a speed constant.

At shutoff, f varies from 1 to 1.15, and at maximum efficiency, f varies from 1.10 to 0.75; an average of 0.95 is accurate enough. To convert H in feet to pressure lb/in^2 , divide H by 2.31 for cool fresh water, or 2.24 for seawater. To determine H for a multistage pump with equal impeller diameters, determine H for one stage and multiply by the number of stages; as an alternate method, determine H for each stage and add the values of H. Because suction pressure is seldom zero, expected discharge pressure should be computed by adding the positive suction pressure to or by subtracting the suction lift (vacuum) from the total head (pressure) developed by the pump.

503-2.6.3.3 Power Required To Drive. The power required to drive any centrifugal pump is determined as follows:

$$WHP = \frac{Gal/Min \times H \times sg}{3960}$$

where

WHP = water horsepower output.

Gal/Min = capacity in gallons per minute.

H = total head in feet of liquid.

sg = specific gravity.

or

$$WHP = \frac{Gal/Min \times P}{1714}$$

where

P = total pressure in lb/in^2,

and the brake horsepower required =

$$\frac{WHP}{\text{pump efficiency}}$$

503-2.6.3.4 Suction Lift. Suction lift exists when the total suction head is below atmospheric pressure. Suction lift is equal to the static lift plus the friction losses in the suction piping. When the liquid supply is above the pump centerline, suction lift may result if the friction losses are greater than the static head. The capability of a pump to operate at suction lift depends on factors such as viscosity, temperature, vapor pressure of the liquid being handled, and the various pump design features, including the suction passages, the impeller design, and the pump speed. If an application requires a high suction lift, pumps that have a larger impeller eye diameter and that run at a slower speed may be chosen. Pump capacity and efficiency are normally unaffected by varying suction conditions until the suction lift exceeds a certain value. At extreme values, the pump may cavitate.

503-2.6.3.5 Cavitation. Pumps cavitate when the absolute static pressure in the liquid drops below the liquid's vapor pressure. When this condition exists, vapor bubbles form. As the liquid develops pressure within the impeller, the bubbles collapse. Severe cavitation will remove material from the impeller. Pump cavitation may result from improper pump design, excessive suction lift, improper pump selection for the specific suction conditions, and improper suction piping arrangement. Cavitation results in pump noise and vibration, reduced capacity and efficiency, and pitting of pump parts, especially the impeller. Cavitation damage is characterized by pitting on the back side of the impeller vane and on the inside of the back shroud, downstream of the suction edge of the vane (Figure 503-2-8). Where cavitation cannot be avoided, special materials resistant to cavitation pitting must be used for impellers and other parts. Condensate pumps usually operate in cavitation and the relationship between capacity and submergence makes them self-regulating as to capacity. A characteristic curve of a pump that operates almost continuously in cavitation is illustrated in Figure 503-2-9.

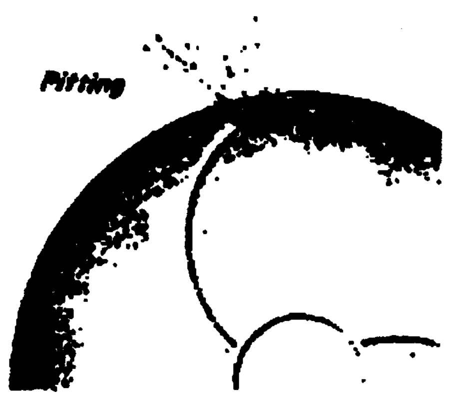


Figure 503-2-8 Pitting Accompanying Cavitation in a Centrifugal Pump

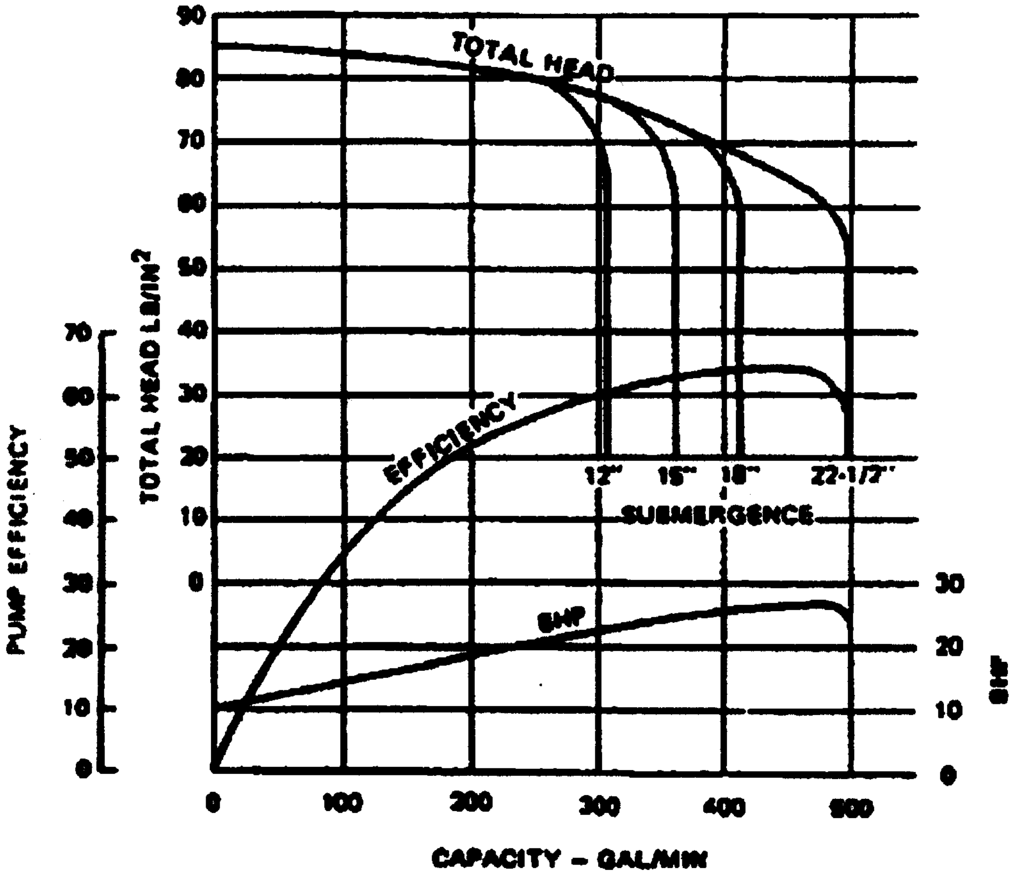


Figure 503-2-9 Characteristic Curve Of A Condensate Pump That Operates Almost Continuously In Cavitation

503-2.6.3.6 Recirculation. A small amount of recirculation occurs at all capacities from the impeller discharge to the suction through the impeller and casing wear ring clearance. Wear will cause the clearance to increase over time and the pump capacity to decrease. Recirculation can also occur in the eye of the impeller when the pump capacity is reduced to about 1/2 to 1/3 of the pump capacity (at the best efficiency point). Recirculation damage is characterized by wear on the inside of the front shroud of the impeller where the vanes begin.

503-2.6.3.7 Net Positive Suction Head. Net positive suction head (NPSH) is the total suction head (pressure) in feet of liquid measured at the pump centerline or impeller eye minus the vapor pressure (expressed in feet) of the liquid being pumped. Two types of NPSH must be considered in selecting pumps:

a. Available NPSH.

b. Required NPSH.

503-2.6.3.7.1 Available NPSH. Available NPSH represents the amount of energy (head) available at the pump suction to get liquid to flow into the pump. In an open piping system, the available NPSH is the sum of atmospheric pressure (in feet of liquid absolute), plus static suction head, (or minus static suction lift) minus suction piping system friction (in feet of liquid), minus the liquid vapor pressure (in feet of liquid absolute), with a correction for the specific gravity of the liquid at the pumped temperature. In a closed system such as a steam condenser or a distilling plant, the pump takes suction from a source under vacuum. The absolute pressure (vacuum) is the vapor pressure of the liquid at the pumped temperature. Under these conditions, the available NPSH is the elevation difference (in feet) between the liquid supply level and the centerline of the pump impeller eye in a vertical plane, minus suction piping system friction (in feet of liquid).

503-2.6.3.7.2 Required NPSH. Required NPSH is determined by the pump manufacturer and depends on the type of impeller inlet, impeller design, pump flow, rotational speed, and nature of the pumped liquid. Required NPSH is usually based on an actual test of nearly identical pumps. For satisfactory operation of the pump, available NPSH must be equal to or greater than the required NPSH throughout the pump operating range to prevent detrimental cavitation.

503-2.6.3.8 System Curves. A pump operating in a system must develop a total head which is made up of several parts, each stated in feet:

a. The difference in height between the source of supply and the point of delivery.

b. The difference in pressures (if any) on the surface of the supply and on the surface of the delivered liquid.

c. Frictional losses in the piping, valves and fittings of the system.

d. Entrance and exit losses at the intake and discharge of the system piping.

e. The difference between the velocity head at the pump suction and the velocity head at the pump discharge.

503-2.6.3.8.1 Because the first two parts vary only slightly with flow, or pump capacity, they can be considered together as type total static head. The other three parts vary (roughly as the square) with flow, or pump capacity, and can be considered together as friction loss.

503-2.6.3.8.2 If, in a system, the total static head is added to the friction loss and the sum is plotted against capacity, the curve that results is the system-head curve. A system-head curve is shown in Figure 503-2-10.

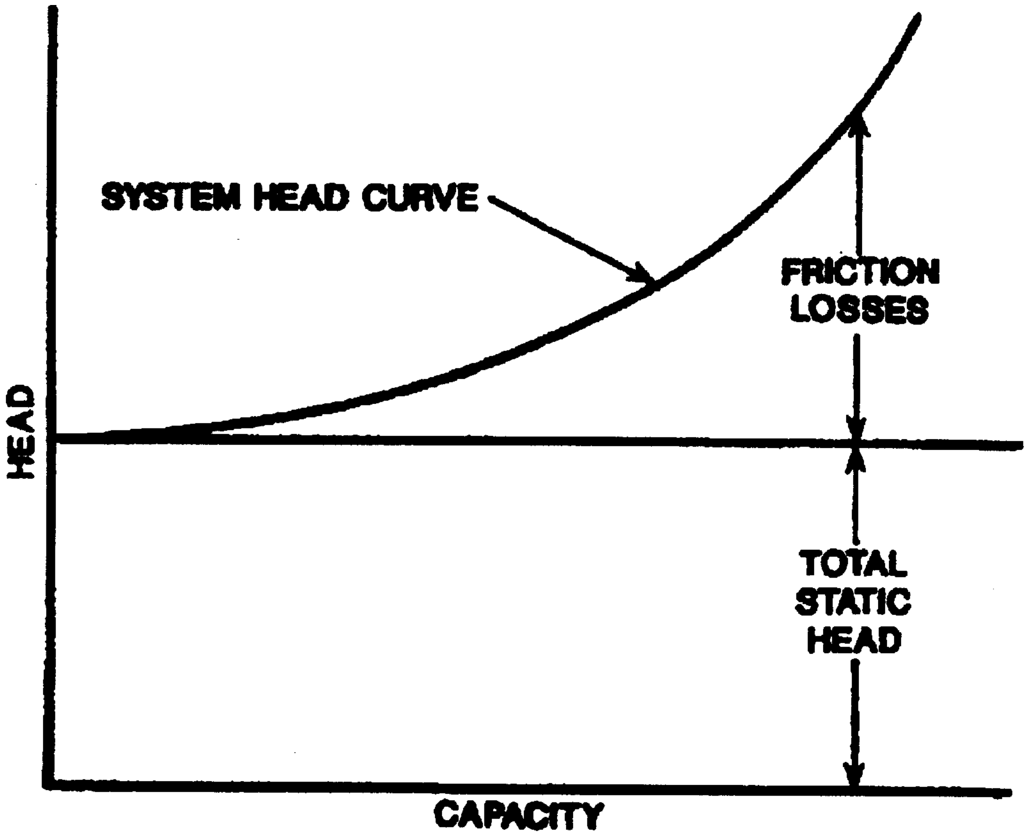


Figure 503-2-10 Friction - Head Curve and System - Head Curve

503-2.6.3.8.3 If the head-capacity curve of a pump, or group of pumps, is plotted together with the system-head curve, the point where the curves cross will be the head and capacity operating point, as shown in Figure 503-2-11.

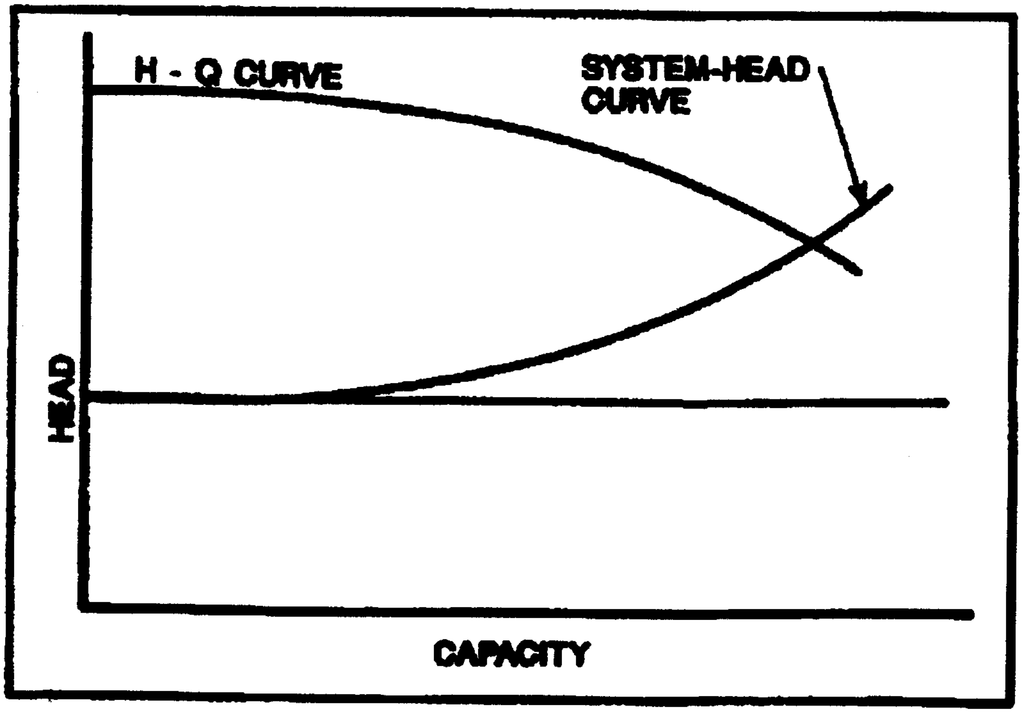


Figure 503-2-11 Pump H-Q Curve Superimposed on System - Head Curve

503-2.6.3.8.4 System operating conditions can also be set by varying the speed of the pump driver as shown in Figure 503-2-12 or by throttling the discharge of the pump, for example, by adding an orifice in the discharge line. The latter case is shown in Figure 503-2-13.

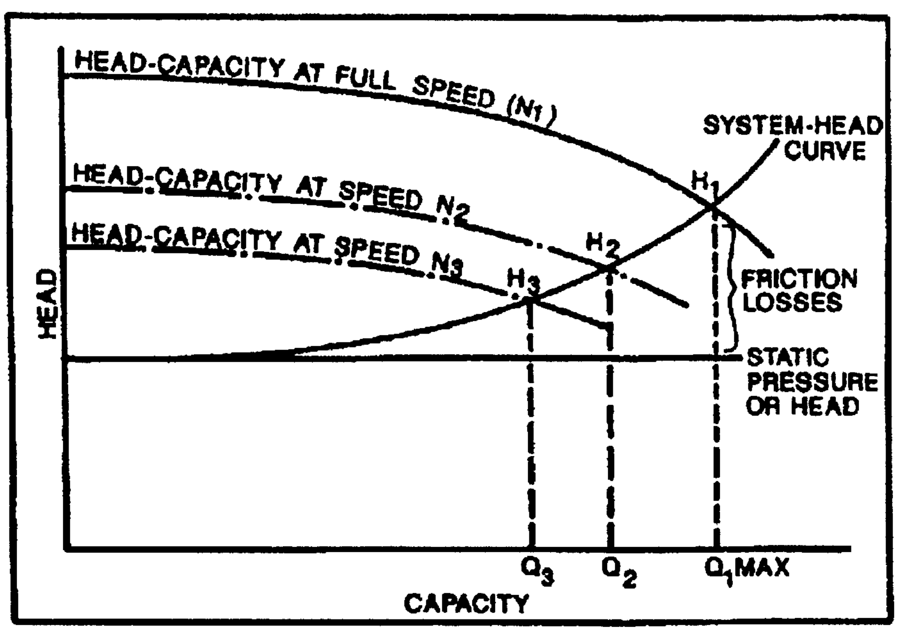


Figure 503-2-12 Varying Pump Capacity by Varying Speed

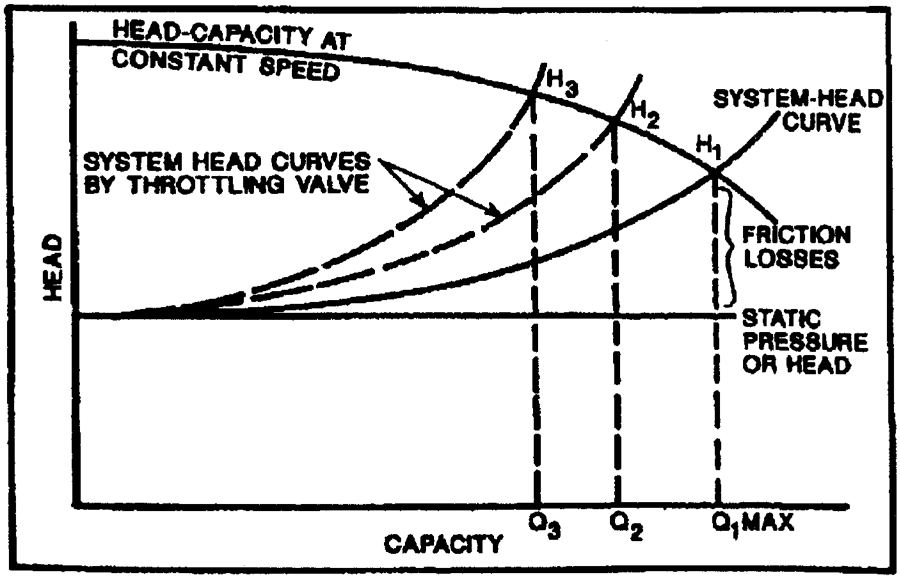


Figure 503-2-13 Varying Pump Capacity by Throttling

503-2.6.3.8.5 Operating conditions can be varied by operating pumps in series or in parallel. The head-capacity curve of two pumps operated in series is constructed by adding the heads of the individual pumps at any capacity, as shown in Figure 503-2-14. The head-capacity curve of two pumps operated in parallel is constructed by adding the capacities of the individual pumps at any head, as shown in Figure 503-2-15.

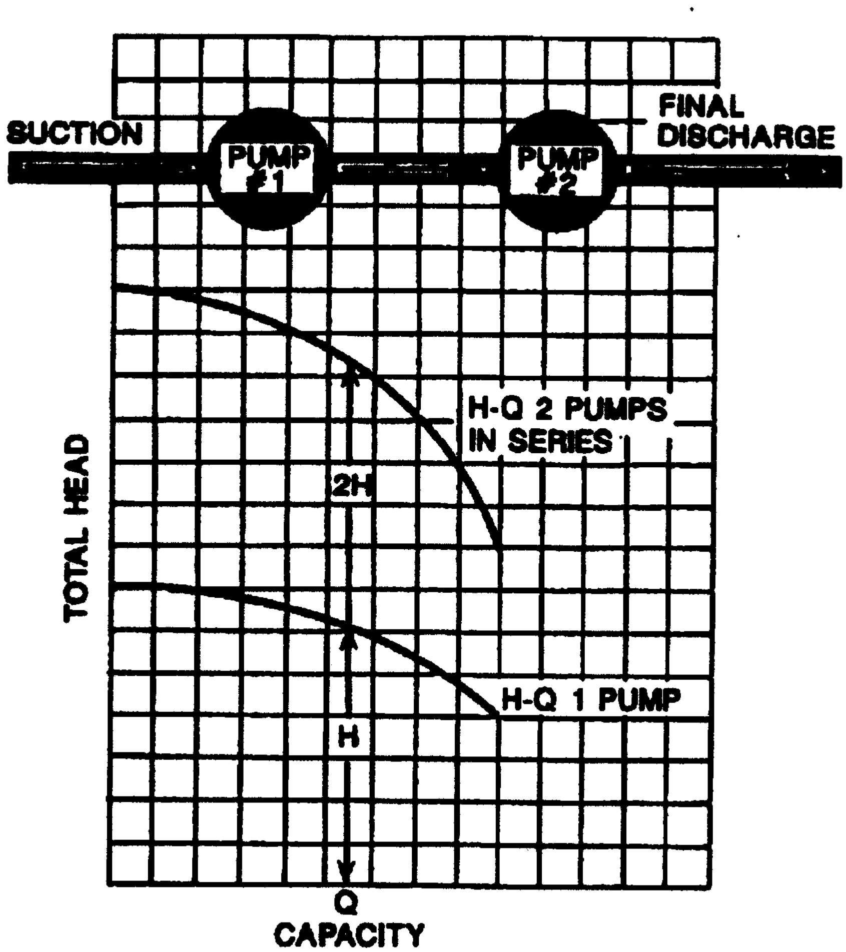


Figure 503-2-14 Operation of Two Pumps in Series

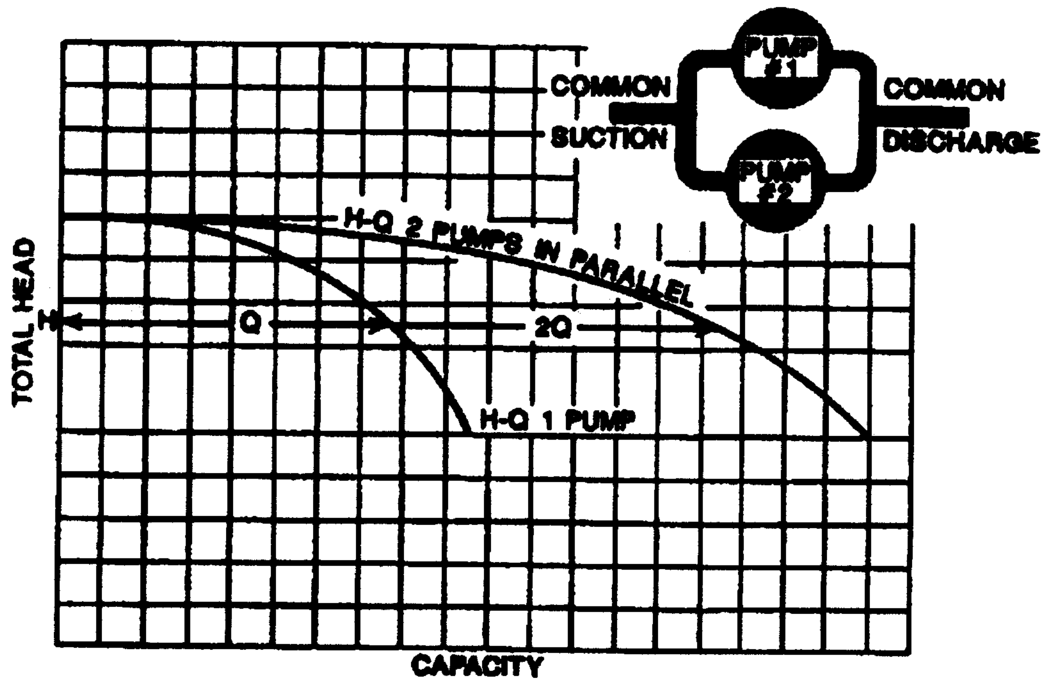


Figure 503-2-15 Operation of Two Pumps in Parallel

503-2.6.3.9 Series Operation. Centrifugal pumps may be arranged to operate in series when the required pressure exceeds that of one available pump, or where it is necessary to install a booster pump between the supply source and the service pump. Examples of series-operated pumps include potable water booster pumps on larger ships, diesel engine circulating water pumps (in which a booster pump is located below the water line) to supply the engine-attached pump on a higher deck, and feed booster pumps installed between deaerating feed tanks and feed pumps. Important principles for such installations are:

a. The booster pump (acting as the first stage) should have the same or slightly greater capacity rating and a lower required NPSH than the pump it feeds.

The booster pump should always be started first and secured last.

503-2.6.3.10 Parallel Operation. Pumps may be installed to operate in parallel to handle varying capacity demands over a wide range or when maximum reliability is required. Examples are main and auxiliary condensate pumps, feed booster pumps, fire pumps, and boiler feed pumps. Operation of several pumps, in parallel, at very low capacities should be avoided to prevent overheating. Pumps should have constantly rising head from rated capacity to shutoff for satisfactory and stable operation in parallel. Where pumps of different capacity ratings are to operate in parallel (such as main and auxiliary condensate pumps), the shutoff head of the smaller pump should be slightly in excess of the shutoff head of the larger pump. This is necessary to ensure that the smaller units are not blocked off the line by the higher pressure developed by one of the larger pumps with which it may be paralleling.

503-2.6.4 APPLICATIONS. The following paragraphs describe various centrifugal pump applications.

503-2.6.4.1 Boiler Feed Pumps. Boiler feed pumps usually are the high speed, multistage type driven by steam turbines. Boiler feed pumps may be horizontal or vertical, and steam turbine or motor-driven.

503-2.6.4.1.1 Different types of feed systems in use are described in **NSTM Chapter 220, Volume 2, Boiler Water/Feedwater, Test and Treatment** . The pressure-closed system is installed on most ships of the active fleet. Feed pumps for this system handle water at 107° C to 121° C (225° F to 250° F) with suction pressures of approximately 50 lb/in^2 g. This is equivalent to an available NPSH of 142 feet; the pump's required NPSH ranges from 42 to 65 feet. Suction pressure is usually supplied by a feed booster pump because the high speed feed pumps would not have sufficient available NPSH. In some auxiliary ships the feed heater is located at a height above the feed pump sufficient to ensure adequate suction head without a feed booster pump. Boiler feed pumps require an NPSH that is sufficient to take care of a momentary or sudden increase in pump capacity.

503-2.6.4.1.2 Feed pumps require recirculation from discharge to supply source, preferably the feed tank or deaerating heater, to protect the pump from overheating when operating at low capacity. The rapid rise in temperature which results when the feed pump operates at low capacity is shown in Figure 503-2-16. To withstand the corrosive action of such feedwater, boiler feed pumps are constructed of corrosion-resisting chrome or chrome-nickel alloy steel.

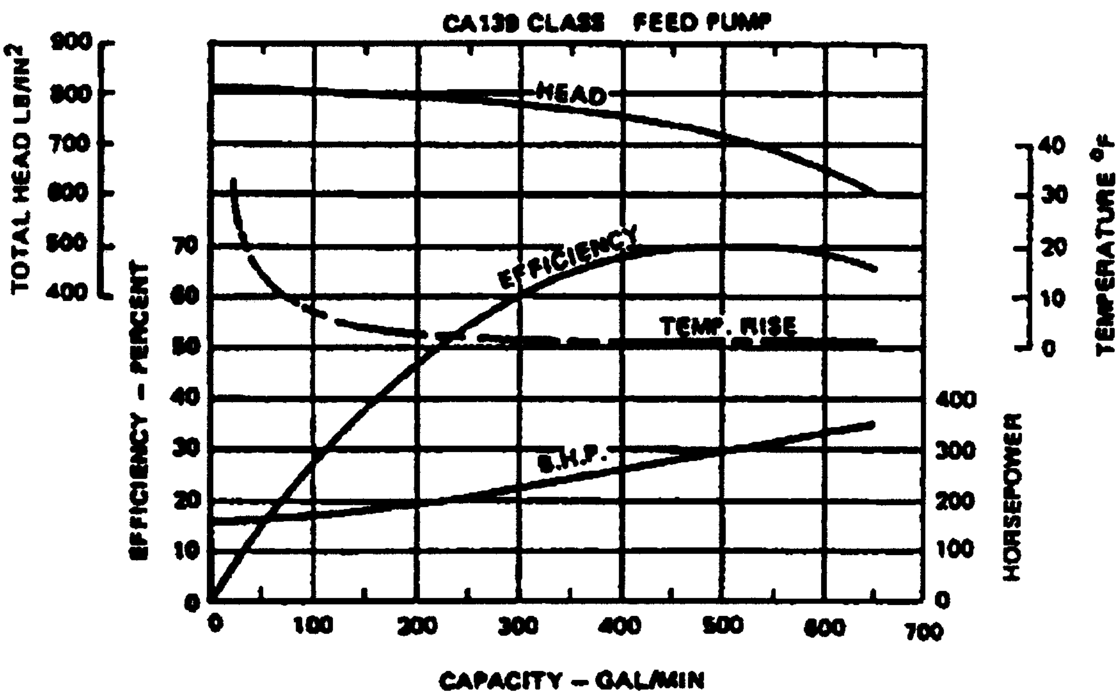


Figure 503-2-16 Curve Illustrating Rapid Rise in Temperature When Feed Pump Operates at Low Capacity

503-2.6.4.2 Feed Booster Pumps. Feed booster pumps are usually vertical, single- or two-stage pumps driven by a steam turbine or electric motor. Their construction is similar to condensate pumps. Feed booster pumps are designed to operate with the same or slightly greater capacity rating and a lower required NPSH than the feed pump. Feed booster pumps take suction from the deaerating feed tank with 6 to 12 feet of static suction head which is about the available NPSH. These pumps are fitted with suction vent connections and a recirculation line back to the feed heater. The recirculation line should be left open when starting or securing and when the pump is discharging to a reciprocating emergency feed or main feed pump. At other times, the recirculation from the centrifugal main feed pump will give the booster pump sufficient protection against overheating at low capacities.

503-2.6.4.3 Condensate Pumps. Main condensate and SSTG (auxiliary) condensate pumps are vertical, single- or two-stage pumps with motor or turbine drives. They are usually installed in parallel. Condensate pump suction piping is arranged with a continuous downward slope from the condenser to the suction nozzle to minimize cavitation and dry operation. Condensate pump elevations are such as to ensure impeller submergence under all conditions of ship pitch or roll. In addition, the condensate pump first-stage impeller is vented back to the condenser. (Figure 503-2-17 shows a typical two-stage condensate pump.)

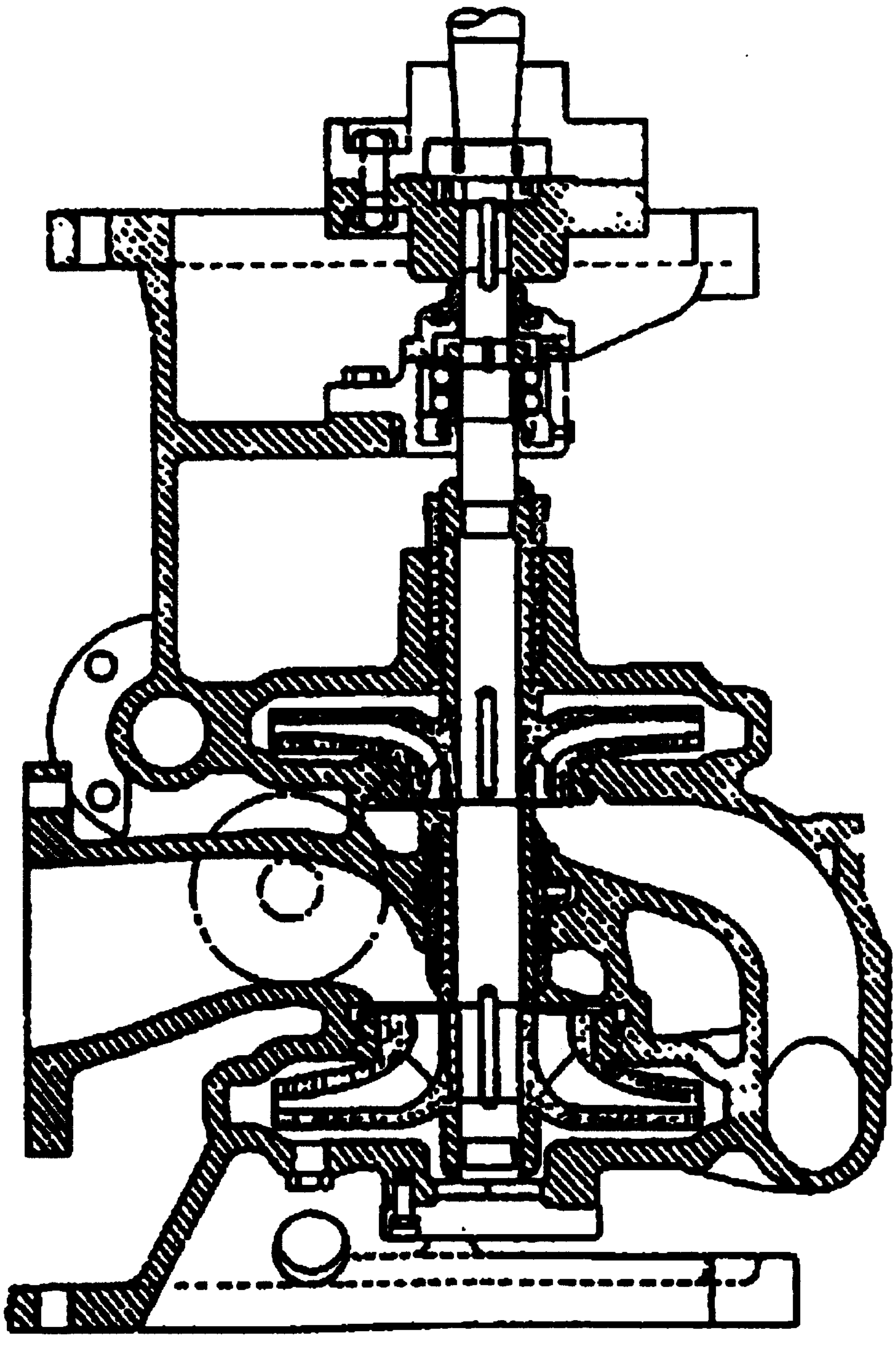


Figure 503-2-17 Typical Vertical Two-Stage Condensate Pump

503-2.6.4.3.1 Condensate pumps take suction from condenser hot wells under extremely low NPSH conditions. Condensate pumps should be operated with nearly continuous recirculation at low capacities because their low NPSH available, over that required, is insufficient to withstand a temperature rise of more than a degree or two without cavitating. First-stage impellers of older condensate pumps are usually of a top suction design, while newer condensate pumps have a bottom suction design to maximize available NPSH.

503-2.6.4.3.2 Sealing water for condensate pump stuffing boxes is taken from a separate supply source to ensure a continuous clean water supply under positive pressure, preventing air leakage into the stuffing box.

503-2.6.4.4 Main Condenser Circulating Pumps. Pumps for main circulating service are usually the vertical, propeller type driven by direct-connected electric motors or geared steam turbines. Their capacities are 10,000 to 40,000 gal/min at total heads of approximately 30 feet. Main condenser circulating pumps usually operate when maneuvering, backing, or going ahead at low ship speed. At high ship speeds, scoop injection is adequate. For auxiliary ships, main circulating pumps are usually the vertical, centrifugal, double-suction type driven by an electric motor. Pump capacity is usually under 10,000 gal/min. Water circulation is essential for condensers in service. Insufficient circulating water can result in vacuum loss and, in the extreme, can result in pressure buildup caused by uncondensed steam, probable expansion joint rupture, and condenser deformation. When switching from scoop injection to the main circulating pump, strict adherence to operating procedures must be observed (see **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors** , for instructions on condensers).

503-2.6.4.5 Miscellaneous Circulating And Supply Pumps. The majority of pumps for applications such as flushing, auxiliary circulating, refrigerator circulating, distiller circulating, and potable water have capacities below 2,500 gal/min at total heads under 100 lb/in^2 . Such pumps are usually of the single-stage centrifugal, volute-type close-coupled to an electric motor. In close-coupled units, the shaft of the motor extends into the pump casing with the impeller secured to the extended motor shaft; the pump casing is bolted to the motor end bell or bearing bracket. The pump casing is fitted with a stuffing box adjacent to the shaft. The stuffing box for these pumps is fitted with a mechanical seal and an auxiliary stuffing box to accept emergency backup packing in case of mechanical seal failure. The shaft is always fitted with a water flinger between the auxiliary stuffing box and the motor bearing bracket so that water leakage from the stuffing box will not follow the shaft and enter the motor housing and bearing. In addition to being bolted to the motor, the pump casing is frequently provided with supporting feet, although this construction is not essential where the shaft overhang beyond the motor is short. The Navy has a line of standard close-coupled pumps. This line includes 12 different-sized casings with motors to suit. Size and location of suction and discharge connections and foundation bolting are interchangeable on standard pumps. Motor shaft extensions and bolting to pump casings are interchangeable so that motors of different manufacturers' are interchangeable on pump casings of the same size.

503-2.6.4.6 Fire Pumps. A Navy standard fire pump has been developed for the 250-, 750-, and 1000-gpm capacities, that is a horizontal single-stage, end suction, volute-type pump close-coupled to an electric motor. The water end parts are made of titanium which resists the corrosion and erosion of seawater applications. Rated capacities and head for fire pumps are listed in Table 503-2-1 (2000-gpm capacity is not a Navy standard design):

Table 503-2-1. RATED CAPACITIES OF FIRE PUMPS

Head (psi)	**Capacity (gpm)**			
125	250	750	1000	----
150	250	750	1000	2000
175	----	----	1000	2000

503-2.6.4.6.1 Prior to the development of the Navy standard design, fire pumps were usually horizontal, single-stage, double-suction type, either electric motor or steam turbine driven. Some of the previous designs are still in use. Emergency fire pumps were usually diesel engine driven.

503-2.6.4.7 Portable Water Pumps. Potable water pumps are usually close-coupled. Pump operation is automatically controlled by a pressure switch to maintain a relatively constant system pressure in the discharge line. A steep head-capacity curve is required for this application.

503-2.6.4.8 Distilling Plant Pumps. Shipboard low-pressure distilling plants require several kinds of basic pumping services. They are:

a. Distiller circulating pump (except the two-stage flash type evaporator).

b. Distiller condensate pump.

c. Brine overboard pump or seawater eductor.

d. Seawater heater drain pump.

503-2.6.4.8.1 Additional services required for certain sizes and plant installations are:

a. Evaporator feed pumps.

b. Distiller fresh water pumps.

503-2.6.4.8.2 Distiller circulating pumps, evaporator feed pumps, and distiller fresh water pumps are usually horizontal close-coupled. Distiller condensate pumps, brine overboard pumps, and seawater heater drain pumps are horizontal close-coupled, vertical-coupled, or vertical close-coupled. Recent installations have used vertical pumps for distiller condensate, brine overboard, and heater drain service to ensure adequate suction submergence and to keep the motors out of locations where they would be subject to splash and drip. Distiller condensate, brine overboard, and heater drain pumps should be made self-venting by installation of a suction pipe which rises continuously without pockets from the pump suction to the evaporator shell or condenser. Where this is impractical, a separate suction vent connection should be provided and lead to a point on the condenser or evaporator shell well above the highest waterline.

503-2.6.4.9 Effect On Cargo Fuel Oil Pumps. Cargo fuel oil pumps handle viscous liquids which can affect centrifugal pump performance. The effects to be expected are:

a. Head and capacity are reduced below those obtained when pumping water except that shutoff head is practically the same.

b. Efficiency is reduced resulting in a greater brake horsepower required for a given capacity.

503-2.6.4.9.1 The changes in performance are caused by increased impeller disk friction losses and the differences in specific gravity. Centrifugal oil pumps, however, have advantages over rotary pumps in weight and space for large pumping capacities. The effects on a cargo fuel oil centrifugal pump when pumping oils of various viscosities are shown in Figure 503-2-18.

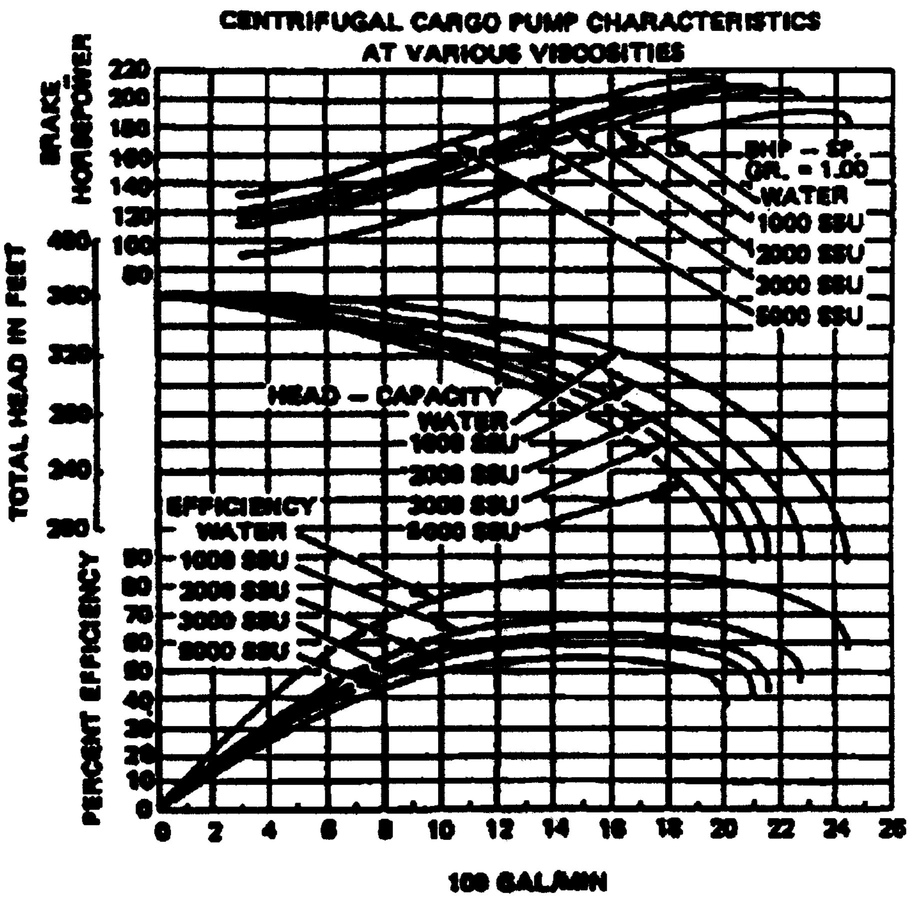


Figure 503-2-18 Effects on Cargo Fuel Oil Centrifugal Pump When Pumping Oils of Different Viscosities

503-2.6.4.10 Regenerative Turbine Pumps. Regenerative turbine pumps, also known as peripheral pumps, are occasionally used for applications involving low capacity and relatively high pressure. They are particularly useful on potable water systems in small ships because they have a steep head-capacity curve.

503-2.6.4.10.1 The flow through the pump is a spiral path between the vanes on the impeller periphery and the casing raceway. The regenerative turbine pump can handle a large percentage of vapor. Construction of a typical pump of this type is shown in Figure 503-2-19.

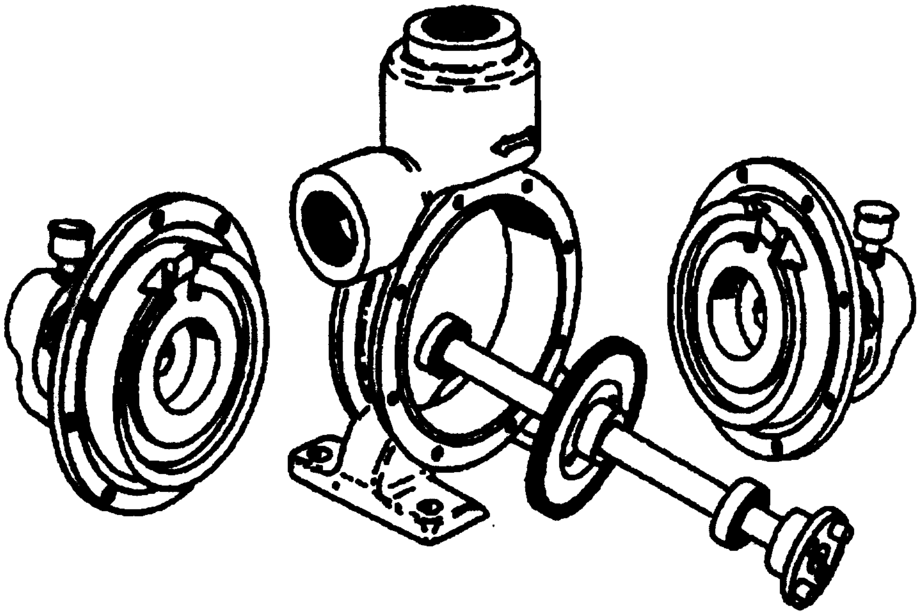


Figure 503-2-19 Construction of a Typical Regenerative Turbine Pump

NOTE

Regenerative turbine pumps have close running clearances which must be maintained to effectively pump liquid; therefore, they are recommended for clean water services only.

503-2.6.4.11 Portable Submersible Pumps. Motor-driven, portable, submersible centrifugal pumps are intended primarily for damage control. Some pumps of this type are stowed semi-permanently with the suction and discharge hose connected for use as drainage pumps. The pumps are furnished with single or three-phase, water-jacketed ac motors at 120, 240, or 440 volts. Minimum performances for these pumps are given in Table 503-2-2.

Table 503-2-2. PUMP MINIMUM PERFORMANCE

Capacity (gal/min)	Total Head (feet)
140	70
180	50

503-2.6.4.11.1 The total heads include 20 feet of suction lift plus hose friction and vertical discharge head. Where the total head required exceeds the head available, two pumps may be coupled for series operation.

CAUTION

Always lower and raise a portable submersible pump by the handling line (rope), never by the electric cable. Secure the handling line to the pump housing through an eye hook installed on the pump for that purpose. Han-

Caution - *precedes*

dling the pump by the cable could break the watertight seal where the cable enters the housing. The power cable may be attached to the handling line if considerable slack is left in the cable.

503-2.6.4.11.2 Each portable submersible pump is furnished with 75 feet of flexible cable that has the controller installed in the cable 30 feet from the pump. Suction and discharge connections interface with Navy standard 2-1/2-inch fire hose. Portable submersible pumps will pass through a hole 10 inches in diameter. Each pump is also provided with a suction strainer which should always be attached when the pump is in use, and with a foot valve which attaches to the suction hose. The foot valve allows water to flow in one direction and prevents the pump casing and suction line from draining when the pump is turned off. The foot valve must be attached whenever the pump is to be located above the water level with only the suction line submerged. Priming is required when the suction line to the pump has drained. Priming may be accomplished by lowering the pump into the water or by filling the pump casing and suction hose with water through the discharge end of the pump, provided the foot valve is attached.

503-2.6.4.12 Portable Engine-Driven Pumps. The portable, engine-driven pumps furnished to the fleet are the P-250, MOD 1, which runs on gasoline; and the P-250, MOD 2, which runs on JP-5. Both pumps operate at 250 gal/min at 125 lb/in^2 . These pumps are dual-service pumps which can be used as either fire pumps or for dewatering flooded spaces. Operation, care, and maintenance of the P-250 pump are described in **NSTM Chapter 555, Volume 1, Surface Ship Firefighting.** .

503-2.6.4.13 Vacuum Priming Pumps. Vacuum pumps are used to prime centrifugal pumps by removing air from the centrifugal pump suction line and pump casing which draws the pumped fluid from the source into the centrifugal pump prior to centrifugal pump startup. Vacuum priming pumps are designed to prime the suction line from the farthest tank in 1 minute, when the tank is less than 5 percent full. Priming pumps are automatically controlled by a pressure switch in the discharge piping of the primed pumps, and by a timing device which stops both the priming and the primed pumps if the discharge pressure is not established within 3 minutes.

503-2.6.4.13.1 Vacuum pumps are also used as part of a package unit to exhaust condensers prior to startup and during operation by drawing the pressure in the condenser below atmospheric pressure.

503-2.7 CENTRIFUGAL PUMP OPERATION

503-2.7.1 GENERAL. Refer to the Engineering Operation Sequence System (EOSS) or the pump technical manual (TM) for specific centrifugal pump preoperation checks, starting procedures, and stopping and securing procedures. Instructions for all pumps cannot be covered here because of the diverse types, designs, and applications in the fleet. The applicable technical manual should be studied before any attempt is made to operate or service the unit. The following general cautions should be observed:

CAUTION

The radial flow pump shall be started with the discharge valve closed. The mixed flow pump and axial flow pump have maximum horsepower requirements at low flow or shutoff conditions; therefore, these pumps should be started with the discharge valve open to avoid overloading and damaging the driver.

CAUTION

Before starting steam turbine-driven pumps, start electric oil pump or crank hand oil pump; and crack open turbine throttle valve sufficiently to remove water from lines, steam chest, and exhaust casing. Failure to remove water may damage the turbine.

503-2.7.2 TROUBLESHOOTING. If the pump does not operate properly, check the common problems and their causes described in paragraphs 503-2.7.2.1 through 503-2.7.2.5.

503-2.7.2.1 No Liquid Delivered. Causes could be:

a. Pump not primed.
b. Pump speed too low.
c. Discharge head too high.
d. Suction lift too high.
e. Impeller passages plugged up.
f. Pump rotation incorrect (for electric motor drive only).
g. Pump impeller installed backward.

503-2.7.2.2 Not Enough Liquid Delivered. Causes could be:

a. Air leaks in suction pipe.
b. Air leaks in stuffing boxes.
c. Pump speed too low.
d. Pump rotation incorrect (for electric motor drive only).
e. Pump impeller installed backward.
f. Suction lift too high.
g. Suction sea chest or suction line not sufficiently submerged.
h. Impeller passage partly clogged.
i. Discharge head too high.
j. Insufficient suction pressure (indicated by noise and fluctuating pressure) for pumping hot or volatile liquids.
k. Mechanical defects including worn wearing rings, damaged or eroded impeller, worn stuffing box packing or mechanical seal, or sleeves in need of replacement.

503-2.7.2.3 Not Enough Pressure. Causes could be:

a. Pump speed too low.

b. Air or gas present in the liquid pumped.

c. Mechanical defects (see paragraph 503-2.7.2.2).

d. Pump rotation incorrect (for electric motor drive only).

e. Pump impeller installed backwards.

503-2.7.2.4 Pump Works For A While, Then Fails To Deliver. Causes could be:

a. Air leakage in the suction line.

b. Air leakage in the stuffing box.

c. Stuffing box water seal plugged.

d. Suction line not sufficiently submerged.

e. Suction lift too high.

503-2.7.2.5 Pump Takes Too Much Power. Causes could be:

a. System head is different than pump rating. For radial flow pumps, the power requirement increases with an increase in flow rate. For axial flow pumps, the power requirement increases toward shutoff. Refer to the manufacturer's power curve to verify if the increased power is due to the pump operating at a point on the head-capacity curve other than rated.

b. Pump speed too high.

c. Specific gravity or viscosity of liquids other than water may be higher than the pump is designed to handle.

d. Mechanical defects, including rotor binding, shaft bent, stuffing boxes too tight, wearing rings worn, or misalignment.

503-2.7.2.6 Excessive Leakage From Stuffing Box.

a. Speed too high.

b. Misalignment.

c. Bent shaft.

d. Interference between rotating and stationary parts.

e. Worn journal bearings.

f. Worn or scored shaft sleeves at packing.

g. Packing installed wrong.

h. Wrong type of packing.

i. Rotor out of balance.

j. Sealing liquid contains dirt and grit, causing scoring.

503-2.7.2.7 Short Life Of Packing.

a. Speed too high.
b. Misalignment.
c. Bent shaft.
d. Interference between rotating and stationary parts.
e. Worn journal bearings.
f. Worn or scored shaft sleeves at packing.
g. Packing installed wrong.
h. Wrong type of packing.
i. Rotor out of balance.
j. Packing gland too tight, preventing lubrication of packing.
k. Sealing liquid contains dirt and grit, causing scoring.

503-2.7.2.8 Vibration Or Noise.

a. Suction pipe or pump not completely filled.
b. Quantity of air or gas in liquid is excessive.
c. Speed too high.
d. Foreign matter in impeller.
e. Misalignment.
f. Bent shaft.
g. Interference between rotating and stationary parts.
h. Worn journal bearings.
i. Damaged impeller.
j. Rotor out of balance.
k. Packing gland too tight, preventing lubrication of packing.
l. Mechanical failure inside pump causes excessive thrust.
m. Excessive bearing temperature.
n. Bearing incorrectly installed.
o. Dirt in bearings.
p. Bearing rusted from water entering housing.

503-2.7.2.9 Short Life Of Bearings.

a. Speed too high.
b. Misalignment.
c. Bent shaft.

d. Interference between rotating and stationary parts.

e. Rotor out of balance.

f. Mechanical failure inside pump causes excessive thrust.

g. Excessive bearing temperature.

h. Bearing incorrectly installed.

i. Bearing rusted from water entering housing.

503-2.7.2.10 Overheating And Seizing.

a. Speed too high.

b. Misalignment.

c. Bent shaft.

d. Interference between rotating and stationary parts.

e. Worn journal bearings.

f. Packing installed wrong.

g. Wrong type of packing.

h. Rotor out of balance.

i. Packing gland too tight, preventing lubrication of packing.

j. Mechanical failure inside pump causes excessive thrust.

k. Excessive bearing temperature.

l. Bearings incorrectly installed.

m. Dirt in bearings.

n. Bearing rusted from water entering housing.

503-2.7.3 LUBRICATION. Lack of lubrication is one of the primary causes of pump failure. Pump bearings are one of these types:

a. Ring-oiled sleeve or ball bearings.

b. Grease-lubricated ball bearings.

c. Oil-lubricated sleeve or ball bearings.

d. Sleeve bearings lubricated by pumped fluid.

503-2.7.3.1 Check ring-oiled bearings to see that oil rings rotate and carry adequate oil. Check oil level frequently.

503-2.7.3.2 Motor-driven pumps and some turbine-driven pumps fitted with ball bearings are usually fitted for grease lubrication. Before starting the pump, ensure that all grease cups and bearing housings are filled with the proper amount of lubricant and that no water or foreign matter is in the bearing housing. Grease lubrication is used to:

a. Lubricate the bearing.

b. Exclude water and foreign matter from the bearing housing.

503-2.7.3.2.1 Ensure that water flingers effectively prevent water (from the pump glands) from following along the shaft and entering the bearing housing. If sleeves fitted on pump shafts leak, replace the O-rings. In an emergency, a flinger can be easily made from a sheet of neoprene.

503-2.7.3.3 Turbine-driven pumps are usually fitted with a self-contained force-lubricating oil system supplied by an attached lubricating oil pump (gear or screw-type). Check the oil pressure and flow to or from all bearings including the thrust bearing, ensuring that the attached lubricating oil pump has primed itself. Ensure that cooling-water is flowing through the oil cooler and that all air is vented from the water side of the oil cooler. It may be necessary to bleed air from the lubricating oil system (to maintain steady oil pressure) by opening air cocks on high points of the lubricating oil system and closing the air cocks immediately when oil appears. Ensure that the oil reservoir is free of water and check the bearing housing to ensure that water from pump or turbine glands is not leaking into the lubricating oil system.

503-2.7.4 VENTS. Petcocks at the highest point of pump discharge and at the pump casing may need to be opened to release air during start up of pump.

503-2.7.5 BYPASS LINES. Friction in centrifugal pumps creates heat which is normally carried away by the liquid being pumped. The heat created frequently results in unacceptable temperature increases at low capacities, particularly for high-pressure pumps. A bypass from the pump discharge to the source of suction supply will eliminate this temperature rise. The bypass for feed pumps is led from pump discharge to the deaerating feed tank or feed heater. The amount of water bypassed necessary to protect the pump may vary by 5 to 15 percent of rated capacity depending on individual pump characteristics. Fire pumps are generally protected by a bypass of 1 to 5 percent. Bypass lines must be kept open whenever the pump is operating.

503-2.7.6 PRIMING. Before any centrifugal pump is started, it should be fully primed. The casing and the suction piping must be filled with the liquid to be pumped. The various ways of priming centrifugal pumps are discussed in paragraphs 503-2.7.6.1 through 503-2.7.6.4.

503-2.7.6.1 A pump with a positive head on the suction will prime itself when the vent on top of the pump casing is opened.

a. After all entrapped air has been released, close the vent valve or cocks.

503-2.7.6.2 If the pump operates on a suction lift, prime the pump by the means provided:

a. If the suction line has a foot or check valve and the discharge line contains liquid, fill the pump casing by opening the bypass valve around the discharge valve. Open vent valves or cocks at the top of the pump case.

After all entrapped air has been released, close vent valves or cocks. If the discharge line has no liquid, open the valve to the independent supply, if provided, or fill the casing by pouring liquid into a funnel inserted in the vent connection on the casing.

b. If the pump is fitted with an air ejector keep the discharge valve closed, open the valve to the ejector from the pump casing and turn on steam or air to the ejector. The pump may be started as soon as the ejector throws liquid continuously. The ejector should be secured after the pump has been started.

c. If the pump is connected to a central priming system, open the valve to the central priming tank, putting the vacuum on the pump case.

d. If the pump is fitted with or connected to a wet-vacuum pump, follow the technical manual for the specific unit. Refer to paragraph 503-2.4.4 for vacuum pump information.

503-2.7.6.3 If a pump does not build up a pressure after priming, it should be stopped and reprimed.

503-2.7.6.4 If the pump is self-priming it is designed to prime itself automatically by an internal hydraulic device or by internal recirculation. Follow the technical manual for the specific unit installed.

503-2.7.7 OPERATION AT BEST EFFICIENCY POINT. Centrifugal pumps should be operated at their rated condition, which is usually the point of best efficiency. Impeller vane angles and liquid passages can be correctly designed for only one point of operation. For any other point of operation the angles and passages are either too large or too small, causing a reduction in pump efficiency at flow points other than design capacity.

503-2.7.8 EXCESS CAPACITY. Any centrifugal pump, if operated at excess capacity and low head, may surge and vibrate (causing bearings and shaft problems) and require excess power.

503-2.7.9 REDUCED CAPACITY. When the pump operates at reduced capacity and higher head, recirculation in the pump can result in impeller, casing, and wearing ring erosion. The radial thrust on the rotor also increases causing higher shaft stresses, increased shaft deflection, and accelerated wear on wearing rings and bearings.

503-2.7.10 MAIN CIRCULATING PUMP WITH BILGE SUCTION CONNECTIONS. When the main circulating pump is operating on bilge suction, the pump should be started the same as for main condenser circulating service. The main injection valve should then be gradually closed and the bilge suction valve opened. When the pump is operating on a high suction lift, as when pumping bilges, the speed should be reduced to two-thirds of rated speed; slowing the pump will minimize but not eliminate pump noise.

503-2.7.11 CHECK VALVE OPERATION. To ensure proper check valve operation do the following. Close the steam throttle valve slightly. This lowers the pump speed and discharge pressure.

503-2.7.11.1 When the pump discharge pressure drops below the pressure of the combined feed discharge main, the check valve should close. This is necessary to prevent backflow of water from the feed discharge mains through the pump when the pump is tripped off the line. The check valve operation can be noted by an indicator, if fitted, or by hearing or feeling it close. A slight water hammer (banging noise) will often accompany the check valve closing. Check valve operation may also be determined by noting that the pressure on the gages shows that the pump discharge pressure is less than the pressure of the combined feed discharge main.

503-2.8 MAINTENANCE

503-2.8.1 GENERAL. The information provided here is intended to supplement preventive and corrective maintenance procedures of the Planned Maintenance System (PMS). Conduct maintenance procedures as specified on Maintenance Requirement Cards (MRCs). If inconsistencies are noted, submit OPNAV 4700/7, PMS Technical Feedback Report (TFBR).

503-2.8.2 USING TECHNICAL MANUALS. Instructions in this chapter for pump maintenance and repair are general for all makes and types. Technical manuals (TMs) are furnished for all pump applications except some small miscellaneous service motor-driven pumps. Technical Manuals contain detailed information concerning the specific pump installed. Instructions in this chapter are of a general nature and are intended to supplement equipment TMs.

503-2.8.3 IN-SERVICE OBSERVATIONS. Make frequent regular inspections of pumps while they are operating. Investigate immediately any change in the sound of a pump. At least once an hour check:

a. Bearing temperature.

b. Stuffing box temperature and leakage.

c. Pressure gauges

503-2.8.4 LANTERN RINGS, SLEEVES, AND FLINGERS. If a stuffing box is fitted with a lantern ring, replace the packing beyond the lantern ring at the bottom of the stuffing box (closest to the impeller) and ensure that the sealing water connection to the lantern ring is not blanked off by the packing.

503-2.8.4.1 Usually, pump shafts are fitted with sleeves in the stuffing box area to protect the shaft from wear due to friction between the packing and the rotating shaft. Ensure that shaft sleeves are tight on the shafts. These are usually secured by keying to the shafts or by screw threads cut in the direction opposite to the shaft rotation. Care should be taken to see that water does not leak between the shaft and shaft sleeves. If shafts or sleeves are roughened or grooved, they should be turned or ground to give a smooth surface (otherwise, keeping shaft sleeves tight will be difficult.)

503-2.8.4.2 Water flingers are always fitted on shafts outboard of stuffing box glands to prevent stuffing box leakage from following along the shaft and entering the bearing housings. Care should be taken to see that flingers are tight on shafts. If flingers are fitted on the shaft sleeves instead of on shafts, ensure that no water leaks under sleeves.

503-2.8.5 CASING WEARING RINGS. The design clearance and the maximum allowable clearance between the impeller and the casing wearing rings are shown on manufacturers' plans and in the individual equipment technical manual.

503-2.8.5.1 When the maximum allowable clearance is exceeded, the wearing rings should be replaced in accordance with the PMS and the individual equipment technical manual. Failure to replace the wearing rings when the allowable clearance is exceeded will result in a decrease of pump capacity and efficiency.

503-2.8.5.2 Allowable clearances are greater on low pressure pumps (circulating pumps) than on medium and high pressure pumps (condensate and feed pumps). As the differential pressure across the wearing ring increases, closer tolerances must be maintained to prevent increased leakage resulting in reduced pump performance.

503-2.8.6 LUBRICATION. Prior to refilling a forced lubrication system with clean oil, the system should be flushed with hot oil (Symbol 2075 or 2110) by pumping flushing oil through it. Immediately after flushing, the flushing oil should be drained from all parts of the system, and the sump tank should be wiped thoroughly with clean, dry rags. Clean lubricating oil should then be pumped through the system for a few minutes.

CAUTION

If Diesel Fuel Marine (DFM) is substituted for flushing oil, there is a danger of damage to the gears and the oil pump if the unit is run at high speed, especially if a worn gear drive is used.

503-2.8.6.1 If flushing oil is not available, a light grade of lubricating oil cut with an equal quantity of DFM may be used.

503-2.8.6.2 The oil reservoir should be checked frequently to ensure that it is free of water. If water is found in the oil, check carefully for pump, turbine glands, and cooler leakage. Clean the oil filters or strainers frequently. With an edge filtration type filter (Cuno or a similar type), drain out sludge and sediment which occasionally accumulate in the bottom of the filter when the unit is not running. The oil in the lubricating-oil system should be renewed whenever the oil becomes emulsified (a milky appearance), foams excessively or when it contains sludge, dirt, or foreign matter. Use Navy symbol 2190 TEP, MIL-L-17331, steam turbine lubricating oil.

503-2.8.6.3 Housings for grease-lubricated ball bearings should be checked occasionally to ensure that the housing is free of water and foreign matter. At that time, check to ensure that bearings are properly locked on shafts. Any water found in the bearing housing should be traced to the source; the presence of water is usually caused by leakage from pump packing. Water should be prevented from entering the housing.

CAUTION

The use of excessive quantities of grease is a major cause of bearing failures.

503-2.8.6.4 The frequency with which grease must be added depends on service of the machine and tightness of the housing seals. Addition of new grease should be in accordance with PMS and technical manual requirements for both quantities and periodicity. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes grease deterioration. Under these conditions, grease separates into oil and minute abrasive particles, becomes increasingly sticky, and tends to seal the bearing against fresh lubricant until the resulting friction, heat, and wear cause a bearing failure.

503-2.8.7 OIL-LUBRICATED SLEEVE BEARINGS. Bearing clearances and crown thickness measurements should be maintained as shown on the manufacturers' plans. Bearing maintenance shall be performed in accordance with applicable PMS and technical manuals. In the absence of bearing clearance information on manufacturers' plans, the values in Table 503-2-3 shall be used.

503-2.8.8 THRUST BEARINGS. Thrust bearings should be examined quarterly and rotor position checked. When checking rotor position, allow for shaft expansion as temperature increases from a cold to a hot running condition.

503-2.8.9 INTERNAL WATER-LUBRICATED SLEEVE BEARINGS. Most types of vertical condensate main circulating pumps are fitted with a water-lubricated sleeve bearing inside the pump casing. If this type of bearing is fitted in a pump, the bearing must be supplied with enough clean water to ensure adequate lubrication and cooling.

503-2.8.9.1 Various materials have been used for internal water-lubricated sleeve bearings, including:

a. Laminated phenolic material, such as fabric-base bakelite or micarta (grade FBM).

b. High lead content bronze.

c. Graphited bronze.

503-2.8.9.2 The condition of all internal water-lubricated sleeve bearings should be checked frequently to guard against excessive wear which would cause misalignment and possible shaft failure.

503-2.8.10 COOLING WATER. Oil coolers or oil cooling coils of all pumps fitted with oil cooling arrangements should be supplied with clean cooling water, usually seawater. A frequent check of oil temperatures should be made to ensure that the cooling system is functioning satisfactorily. This is particularly important on high-speed boiler feed pumps and on turbine-driven units fitted with worm-gear type reduction gears.

503-2.8.11 CARE OF DRIVING UNITS. Instructions are given in the Naval Ships Technical Manual for maintenance of diesel engines (**NSTM Chapter 233**), auxiliary steam turbines (**NSTM Chapter 502**), and electric motors and controllers (**NSTM Chapter 302**).

503-2.8.12 COUPLINGS. Many pumps are connected to the driver shafts with flexible couplings. These couplings permit slight movement of the pump and driver shafts while transmitting power. Maintenance requirements for satisfactory coupling life are lubrication (if required), alignment, and balance.

503-2.8.12.1 Coupling Maintenance. Coupling maintenance should be accomplished in accordance with the PMS. When performed, PMS coverage and periodicity are considered adequate to ensure proper coupling lubrication and alignment, provided there are no obvious operational defects such as undue vibration or noise.

Table 503-2-3. CENTRIFUGAL PUMP SLEEVE BEARING CLEARANCES (WHITE METAL)

Journal		Bore of Bearing		
Diameter	**Tolerance**	**Minimum Diametral Clearance, Journal and Bearing**	**Tolerance**	**Wear at Which Bearings Should be Renewed**
1	+0.000 -0.001	0.0025	+0.001 -0.000	0.0075
2	+0.000 -0.001	0.003	+0.001 -0.001	0.0075

Table 503-2-3. CENTRIFUGAL PUMP SLEEVE BEARING CLEARANCES (WHITE METAL) - Continued

Journal		Bore of Bearing		
Diameter	Tolerance	Minimum Diametral Clearance, Journal and Bearing	Tolerance	Wear at Which Bearings Should be Renewed
3	+0.000 -0.001	0.004	+0.001 -0.000	0.010
4	+0.000 -0.001	0.005	+0.001 -0.000	0.015

Note

These clearances are to be used only in the absence of other instructions, including approved plans. Allowable wear indicated is approximate only, and is based on average wear ring clearances.

503-2.8.12.2 Non-Lubricated Couplings On Main Feed Pumps. Machalt 255-30001 (ECP-110) converts main feed pump couplings from a lubricated flexible coupling to a non-lubricated flexible coupling. If installed, check the non-lubricated flexible coupling for wear in accordance with the PMS and pump technical manual. Do not lubricate this coupling.

503-2.8.12.3 Lubrication. Standardized procedures and precautions which should be observed when lubricating the coupling are described in paragraphs 503-2.8.12.3.1 through 503-2.8.12.3.3.

CAUTION

Do not leave the grease fitting in the coupling because imbalance will result.

503-2.8.12.3.1 For grease-lubricated couplings, remove the two lube plugs (180 degrees apart) and position the coupling for horizontal installations so that one hole is 45 degrees above the horizontal. Install the grease fitting in the top hole and apply grease (DOD-G-24508) until the excess grease flows out of the lower opening. Remove the grease fitting and reinstall both plugs.

503-2.8.12.3.2 The oil should be drained from the oil-lubricated couplings and the couplings should be refilled with the specified oil to the correct oil level as directed by the PMS. This also should be done after any pump overhaul.

503-2.8.12.3.3 During the coupling lubrication, watch for loss of lubricant. Leakage may occur through the coupling flange if the bolts are loose, damaged, or if the gasket is missing. Flanged flexible couplings that require lubrication should have a gasket between the coupling flanges. Usually the gasket thickness is 1/64 inch. Consult the manufacturer's technical manual for the recommended gasket and flange O-rings.

503-2.8.12.4 Imbalance. Vibration can be caused by imbalance. The couplings are balanced as a set and match-marked. The hub should be aligned by the match marks before reassembly. The flanges should also be reassembled with attention given to their match marks. The nuts and bolts are also numbered in specific holes which are usually numbered. If the numbers cannot be located, the holes, bolts, and nuts should be numbered during disassembly for identification during reassembly.

503-2.8.12.5 In most cases, close attention to coupling lubrication (if required), alignment, and balance will prevent coupling failure. When a coupling failure occurs, the failed coupling should be sent to Commanding Officer, Naval Surface Warfare Center Ship System Engineering Station (NAVSURFWARCEN), (Code 023C), Philadelphia, PA 19112, for assistance in determining deficiencies.

503-2.9 SPEED-REGULATING AND SPEED-LIMITING GOVERNORS

503-2.9.1 GENERAL. All turbine-driven units are fitted with a speed-regulating (constant speed) or speed-limiting governor.

503-2.9.2 SPEED-REGULATING (CONSTANT SPEED) GOVERNOR. The speed-regulating (constant speed) governor, by its control and regulation of the steam admission to the turbine, automatically maintains the speed of the turbine at a predetermined value, under all conditions of load and exhaust pressure, within the limits of design of the turbine. For additional information refer to **NSTM Chapter 502, Auxiliary Steam Turbines** .

503-2.9.3 SPEED-LIMITING GOVERNOR. The speed-limiting governors, by control of the steam admission to the turbine, will not permit the turbine to operate at a speed in excess of the governor set point, but will permit the turbine to continue in operation at this speed. The speed-limiting governor is a safety device that protects the turbine from an overspeed condition. For additional information refer to **NSTM Chapter 502, Auxiliary Steam Turbines** .

CAUTION

These governors shall never be lashed down or otherwise rendered inoperative.

503-2.9.4 SET LIMITS. The governor should be set to give rated speed at rated load conditions, and, with this setting, turbine speed should not exceed the rated speed by more than 5 percent for any condition of load including pump shutoff. If the governor does not function within the set limit, it should be repaired. For satisfactory parallel and series feed booster pump and boiler feed pump operations, governors of all identical pumps must be set for the same speed.

503-2.9.5 OVERSPEED TRIPS. Turbines equipped with speed-regulating governors are fitted with an overspeed trip which is a safety device that shuts off steam to the turbine after a predetermined speed has been reached. This predetermined speed is about 110 percent of normal operating speed. For additional information on overspeed trips, refer to **NSTM Chapter 502, Auxiliary Steam Turbines** .

CAUTION

Overspeed trips shall never be lashed down nor otherwise rendered inoperative.

503-2.10 PUMP PRESSURE - REGULATING GOVERNORS

503-2.10.1 GENERAL. In addition to speed-regulating and speed-limiting governors, turbine-driven boiler feed pumps and fire pumps are fitted with pump pressure-regulating governors which are automatic throttling valves installed in the steam supply line to the turbine. Variations in pump discharge pressure or in pressure differential actuate the governor causing it to vary the steam flow to the turbine, thereby regulating pump speed. For additional information on pump pressure-regulating governors, refer to **NSTM Chapter 502, Auxiliary Steam Turbines** .

503-2.10.2 LOW SUCTION PRESSURE TRIPS. Turbine-driven boiler feed pumps are also fitted with low suction pressure trips that monitor the pressure in feed pump suction lines and when the pressure decreases to a predetermined level, the steam flow to the turbine is interrupted and the pump is shut down. The low suction pressure trip ensures that adequate fluid pressure is available at the inlet of the feed pump. For additional information on low suction pressure trips, refer to **NSTM Chapter 502, Auxiliary Steam Turbines** .

CAUTION

Low suction pressure trips shall never be gagged or otherwise rendered inoperative.

503-2.11 TESTS AND INSPECTIONS

503-2.11.1 Centrifugal pumps should be tested or inspected periodically in accordance with PMS requirements. The procedures given in paragraphs 503-2.11.2 through 503-2.11.4 are intended to be used as a general guide and are not inclusive of all tests or inspections required by PMS.

503-2.11.2 Periodically, in accordance with authorized PMS, operate all pumps by steam or power. If power is not available, move pumps by hand. Lubricate the pressure regulating governor (for types requiring lubrication). Check lubricating oil for water and contamination. Periodically, check the thrust position of the pump rotor. As necessary, sound and set up on all foundation bolts, and secure all foundation dowel pins. Periodically, check sleeve bearing clearance by leads or crown thickness measurements as described in **NSTM Chapter 244, Propulsion Bearings and Seals** .

503-2.11.3 During the overhaul cycle, check internal water-lubricated sleeve bearings and shafts for wear and scoring. Open pump and reduction gear casings for inspection and cleaning. Check clearance of all diaphragms and casing throat bushings, impeller and casing wearing rings, pressure breakdown drums and bushings. Renew as necessary.

503-2.11.4 These periodic tests and inspections are the minimum necessary to ensure safe and reliable equipment operation. Indications of low discharge pressure or other manifestations of improper operation require more frequent or more extensive tests and inspections. Seawater and brine pumps should be opened and inspected as performance dictates. In general, pumps should be turned over and lube oil checked each time a unit is placed in service. Cleaning of lube oil sumps should be dictated by oil condition. The degree of oil contamination will dictate the necessity for further inspection of bearings and journals. For turbine tests and inspections, see **NSTM Chapter 502, Auxiliary Steam Turbines** .

503-2.12 REPAIRS

CAUTION

Only qualified personnel should attempt repair of these pumps.

503-2.12.1 GENERAL. The repair and overhaul of a pump are intended to restore it to its original performance profile and not necessarily intended to return the overhauled pump to the original manufacturer's drawing tolerances. In the process of overhauling a pump, the worn or damaged subcomponents are either replaced or repaired. The Supervisors Work Specification shall identify the class of overhaul (i.e., Class B) authorized for the item. Definition of overhaul class is provided in General Specification for Overhaul (GSO) Section 042. Where applicable, the Supervisors Work Specification shall invoke the overhaul of the item to be accomplished in accordance with an approved Technical Repair Standard (TRS). Where an approved TRS does not exist, or is not authorized, the overhaul of the item or system (i.e., valve, pump, filter, pipe) shall be in accordance with applicable drawings or technical manuals as modified by the overhaul criteria paragraphs in GSO Sections 503 and 505.

503-2.12.2 ASSEMBLY DRAWINGS. When repairing a pump or making an interior pump examination, have at hand all drawings and available dimensional data pertaining to the pump. Bearing bridge gage readings, clearances between the impeller and casing wearing rings, water seal clearances, or gland adjustments must be corrected if these dimensions have become altered. Altered dimensions result in poor operation which will continue in spite of other major repairs, unless dimensions are correct.

503-2.12.3 WEARING PARTS. Centrifugal pump parts most frequently requiring repair or replacement are described in paragraphs 503-2.12.3.1 through 503-2.12.3.4.

503-2.12.3.1 Casing Rings. Casing rings keep the internal bypassing of liquid to a minimum, thereby maintaining the pump's efficiency. Clearances should be checked periodically and whenever the pump casing is opened. If the clearance exceeds the specified clearance stated in the manufacturers' plans or pump technical manual, replace the rings.

503-2.12.3.2 Shaft Sleeves. Operating personnel frequently take up too hard on the packing in an attempt to stop stuffing box leakage; this causes shaft sleeve scoring. Sleeves should be examined whenever a pump is opened, and, if only slightly scored, they should be smoothed; when worn, they should be replaced.

503-2.12.3.3 Sleeve Bearings. Worn sleeve bearings cause the rotor to drop which causes wear of casing and impeller rings. Inspect the condition and contact pattern of the bearing. Bearing babbitt contact is indicated by the polished portion of the bearing surface. Slight circumferential grooving and localized wipes indicated by shiny spots are acceptable, but babbitt build-up requires removal. Unacceptable conditions are wiping, heavy or extensive circumferential grooving, pitting, cracks, embedded dirt, loose babbitt, and discoloration ranging from gray to black, which indicates corrosion and oxidation. Repair or replace the bearing shell if these conditions exist. Bearings of centrifugal pumps should be rebabbitted in accordance with **NSTM Chapter 241, Propulsion Main Reduction Gears, Couplings and Associated Equipment** , when bridge readings or leads show that maximum allowable wear has occurred. The oil clearances for bearings will be found in the manufacturers' plans or instruction books. In the absence of such data, tolerances given in Table 503-2-3 should be followed.

503-2.12.3.4 Bushings. Bushing clearances should be measured whenever the pump is opened. Bearing wear can cause bushing wear, and bushings should be renewed after bearings are restored to their original dimensions.

503-2.12.4 INSPECTION AND REPAIR OF PUMP PARTS. The inspection and repair methods required for pump part repairs are described in paragraphs 503-2.12.4.1 through 503-2.12.4.2. Refer to GSO Section 503 for specific inspection and repair information.

503-2.12.4.1 Inspection Of Pump Parts. Pump parts may be inspected at the IMA or Depot level by several methods. The following information is provided here as a list of inspection methods and applicable specifications.

503-2.12.4.1.1 Nondestructive inspection is used to determine whether pump parts are defective without destroying the parts. Several methods are used and shall be performed in accordance with MIL-STD-271.

a. Magnetic particle test is used to detect surface or subsurface discontinuities in ferromagnetic materials. Finely divided ferromagnetic particles are applied over the material surface and when the material is magnetized some of the particles will be gathered by the leakage field. This magnetically held collection of particles forms an outline of the discontinuity and generally indicates its location, size, shape and extent. See NAVSEA 0900-LP-003-8000 for acceptance criteria.

b. Liquid penetrant test is used on non-magnetic (non-ferrous and austenitic corrosion-resisting or stainless steel) material parts that contain suspect surface discontinuities. Sometimes called dye penetrant test, a colored dye is poured onto the surface of the casting and the dye will collect in any cracks or surface discontinuities that exist. See NAVSEA 0900-LP-003-8000 for acceptance criteria.

c. Radiography is the process of taking X-rays of the part to determine the integrity and soundness of the casting. Radiography detects subsurface (internal) defects or discontinuities.

d. Brinell hardness is a process used to determine how hard the material is and this number can then be compared to the material specification.

e. Chemical analysis is used to determine whether the material has the correct chemical composition.

503-2.12.4.1.2 Threaded parts are inspected for burnished, galled, crossed, torn, cracked, deformed, or missing threads. Significantly damaged threads can reduce the strength and integrity of a joint.

503-2.12.4.1.3 Wall thickness is inspected to determine the pressure containing ability of a casting. If the wall thickness is reduced beyond a critical dimension due to erosion or corrosion, the casting could rupture or leak.

503-2.12.4.1.4 Sealing surfaces are inspected to determine the pressure containing ability of a joint. If the sealing surface contact area is reduced beyond a critical amount due to erosion or corrosion, the joint could leak.

503-2.12.4.1.5 Keyways and keys are inspected for deformed, cracked or chipped edges, or high spots. These conditions can result in a failed key or an improper fit between parts. If the key fails, the equipment will not rotate.

503-2.12.4.1.6 Gear teeth are inspected for cracks, nicks, or abrasion. These conditions can result in failed gear teeth and inhibit the smooth operation of the equipment.

503-2.12.4.2 Repair Of Pump Parts. Pump parts may be repaired at the IMA or Depot level by several methods. The following information is provided here as a list of repair methods and applicable specifications.

503-2.12.4.2.1 Weld repair consists of depositing weld material on a casting to build up an area which is then remachined to the original dimension. Weld repair of pump casings and internals, including pump bore repair, shall be accomplished in accordance with MIL-STD-278. Weld repair is normally used for repairing eroded or damaged casings, building-up wear ring seating areas, and repairing gasket mating faces. Weld repair of rotating parts is prohibited.

503-2.12.4.2.2 Impregnation is a process that seals porosities in castings by introducing sealant into the casting pores by pressure or vacuum techniques. Impregnation is permitted, only with NAVSEA approval, on structurally sound nonferrous castings to seal leakage due to porosity or other nonstructural defects. Castings shall be inspected and repaired in accordance with MIL-STD-278 and impregnated in accordance with MIL-STD-276. Sodium silicate shall not be used for impregnation.

503-2.12.4.2.3 Thermal spray coating is a process used for repair and corrosion protection of ferrous and nonferrous pump metal parts. This process is used only when the amount of material buildup required is a thin layer. Thermal spray coating shall be accomplished in accordance with MIL-STD-1687 and is approved by NAVSEA for the following repairs:

a. Repair of static fit areas to restore original dimensions, finish, and alignment.

b. Repair of seal (including packing) areas to restore original dimensions and finish.

c. Repair of fit areas on shafts to restore original dimensions and finish.

503-2.12.4.2.4 Brazing repairs are restricted to reattachment of piping connections on pumps and shall be accomplished in accordance with NAVSHIPS 0900-LP-001-7000.

503-2.12.4.3 Emergency Rebabbitting Of Small Bearings. To rebabbitt a small bearing in an emergency, coat the journal heavily with banana oil (amyl acetate, TT-A-511D), and with the shaft properly centered in the bearing housing, pour the babbitt around the journal. The bearing will break clean from the journal and can then be used with little or no scraping in.

503-2.12.5 EMERGENCY PUMP REPAIRS USING EPOXY-BASED COMPOUNDS. In recent years, epoxy-based compounds have been developed for repairing mechanical equipment. NAVSEA has approved the use of specific products for certain applications as temporary repairs only. These repairs are permitted only when conventional repair methods (i.e., weld repair or electroplating) are not achievable. These repairs require case basis approval of NAVSEA 05Y21.

503-2.12.6 IMPELLER CENTERING. It is essential to the best centrifugal pump operation that the centers of the impeller exit passages line up accurately with the centers of casing or diffuser waterways; otherwise, excessive turbulence and friction losses may occur, and the thrust load may be increased.

503-2.12.7 ALIGNING PUMP. Pumps should be periodically checked for alignment because piping strains may develop, distorting the unit. Bearing wear and distortion of supporting structure may also contribute to misalignment. Pumps should be aligned in accordance with Section 6 of this chapter.

503-2.12.8 BALANCING. Vibration can be caused by imbalance. The couplings are balanced as a set and match-marked. The hub should be aligned by the match marks before reassembly. The coupling flanges should also be reassembled, aligning match marks.

503-2.12.8.1 The nuts, bolts, and holes are usually numbered; however, if numbers cannot be located, the holes, bolts, and nuts should be numbered during disassembly for identification during reassembly.

503-2.12.8.2 All pump and driving unit rotating parts are balanced dynamically for all speeds from 0 to 125 percent of rated speed. The parts are usually balanced on a balancing machine to ensure accurate balance. Balancing machines are usually available only at naval shipyards. A portable balancing outfit is available on tenders for use by individual ships. With a portable unit, the pump and turbine rotors may be balanced in place. Whenever possible the balancing machine or portable balancing outfit should be used in preference to any other method of balancing.

SECTION 3.

ROTARY PUMPS

503-3.1 ROTARY PUMP SAFETY PRECAUTIONS

503-3.1.1 The following safety measures must be followed exactly to minimize hazards to personnel and equipment while operating rotary pumps:

1. Ensure that relief valves, where fitted, are tested and that they function at the designated pressure.
2. Never attempt to jack a pump by hand when the steam valve to the driving unit is open.
3. Do not tie down or otherwise render inoperative the overspeed trip, speed-limiting, or speed-regulating governors.
4. In accordance with PMS, check the setting of the overspeed trip, if fitted. Ensure that overspeed trips are set to shut off all steam to the unit when rated speed is exceeded by 10 percent.
5. As specified in PMS, check the setting of speed-limiting and speed-regulating governors where fitted. Ensure that settings limit the speed of the unit to rated speed under rated conditions and that rated speed is not exceeded by more than 5 percent for any loading condition.
6. Never operate a positive displacement rotary pump with a discharge valve closed unless the discharge is protected by a properly-set relief valve of a size sufficient to prevent a dangerous rise in pressure.
7. When inspecting or overhauling vertical rotary pumps, never rely on a flexible coupling to support the total pump rotor weight. Before working on pump rotors, support them with wire rope slings, block and tackle, or chocks.
8. Never close the suction valve while power is being supplied to a rotary pump prime mover. The lubricating fluid film on the rotors, idlers, and pump liners will be lost immediately, and this loss may cause catastrophic pump failure if not corrected immediately (see caution preceding paragraph 503-3.6.1.2.1).
9. Ensure that drains are open and that steam and exhaust root valves are wired shut and tagged DO NOT OPEN before opening the turbine-driven unit steam end. If double valve protection is provided, wire both valves shut.

503-3.2 GENERAL DESCRIPTION

503-3.2.1 Positive displacement rotary pumps have largely supplanted reciprocating pumps for pumping all types of viscous fluids on naval ships. Rotary pumps are also used for gasoline or other low viscosity volatile fluids where a high suction lift is required and service is intermittent.

503-3.2.2 Rotary pumps achieve a high efficiency through close clearances and are sensitive to corrosive fluids or fluids containing abrasive solids; this factor is particularly important for rotary pumps handling distillate fuels because any entrapped hard solids can cause premature wear of pump rotors or their bores.

503-3.2.3 Care must be used to ensure proper fuel management to prevent a minimum of solids passing through the pumps (see **NSTM Chapter 541, Ship Fuel and Fuel Systems**). In general, rotary pumps are self-priming.

503-3.3 ROTARY PUMP TERMINOLOGY

503-3.3.1 The following terminology applies to rotary pumps:

a. Pumping chamber **-** The pumping chamber is a space formed by the body of the pump and its end plate(s) into which fluid is drawn and from which the fluid is discharged by the action of the rotor(s).

b. Rotating assembly **-** The rotating assembly consists of all parts which rotate with the pump shaft.

c. Body **-** The body surrounds the periphery of the pumping chamber. It is sometimes referred to as a casing or housing.

d. End plate **-** An end plate closes each end of the body to form the pumping chamber. One or more end plates are used depending upon the construction of the pump. It is sometimes referred to as a head or cover.

e. Rotor **-** A rotor is a part which rotates in the pumping chamber. One or more rotor(s) are used per pump. It is sometimes referred to by a specific name such as gear or screw.

f. Bearing **-** A bearing supports or positions the shafts on which a rotor is mounted. A bearing may be internal (bearing being wetted by the fluid being pumped) or external (bearing isolated from the fluid being pumped). The bearings may be either an antifriction (roller or ball bearing) or fluid film type (sleeve and journal).

g. Timing gear **-** A timing gear transmits torque from one rotor shaft to another, and to maintain the proper angular relationship of the rotors.

h. Radial seal **-** A radial seal provides a seal on its outside diameter. Examples of radial seals are O-rings and U cups.

503-3.4 DESCRIPTION

503-3.4.1 GENERAL. Rotary pumps are positive displacement pumps. They consist of a casing containing a rotating assembly running in close clearances and in such a manner that fluid is trapped in a moving space or chamber formed by the rotor and casing. As the rotor turns, the fluid is carried to the discharge side of the pump where it is pushed or squeezed from the pumping space to the discharge. The rotor assembly may consist of pairs of intermeshing gears, screws, lobes, cams or sliding pistons, vanes, blocks, or other forms. Rotor assemblies more common to the naval service are described in this section.

503-3.4.2 CLASSIFICATION AND TYPES. Rotary pumps are classified according to service or application and the manufacturers' name or trade name. This method of identification is more commonly used for rotary pumps than for other types of pumps.

503-3.4.2.1 Most manufacturers specialize in only one or two rotor types with the following significant design characteristics:

a. Screws without timing gears (Figure 503-3-1): The fluid is carried in spaces between screw threads and is displaced axially as they mesh. The power rotor screw threads drive the idler rotors by meshing with them.

b. Screws with timing gears (Figure 503-3-2): The fluid is carried and displaced in the same fashion as a screw pump without timing gears; however, timing gears are used to transmit torque from one rotor shaft to another, and to maintain the angular relationship of the rotors.

c. Cam and plunger: The Warren quadruplex pump end consists of four valve chambers connected by suction and discharge manifolds. The suction and discharge valve assemblies are in-line and straddle the pumping plungers. The pumping plungers are threaded into slippers which are guided by hardened guides. The slippers also secure the follower bearings through which the forward motion of the plungers are transmitted from the cam shaft to the plunger.

d. Gear: The fluid is carried between the gear teeth and the wall of the pump chamber and is displaced when they mesh. External gear (spur, helical, or herringbone) pumps (Figure 503-3-3 and Figure 503-3-4) have all gear rotors cut externally. Internal gear pumps (Figure 503-3-5) have one rotor with internally cut gear teeth that mesh with an externally cut gear.

e. Sliding vane (Figure 503-3-6): The sliding vane uses a rotor with sliding vanes to draw the liquid in behind the sliding vane, through the inlet port, and into the pumping chamber. As the rotor turns, the liquid is transferred between the vanes and forced through the outlet.

f. Sliding shoe (Figure 503-3-7): The pumping action is derived from the rotation of three or more eccentric discs on a single rotor, each of which is closely fitted into a displacement chamber or shoe. The eccentric movement of each disc is comprised of horizontal and vertical components. The horizontal motion provides displacement, the disc reciprocating in the shoe like a piston in a cylinder. The vertical motion controls the valving and the entry and discharge of the fluid by moving the shoe up or down to uncover or cover the appropriate ports.

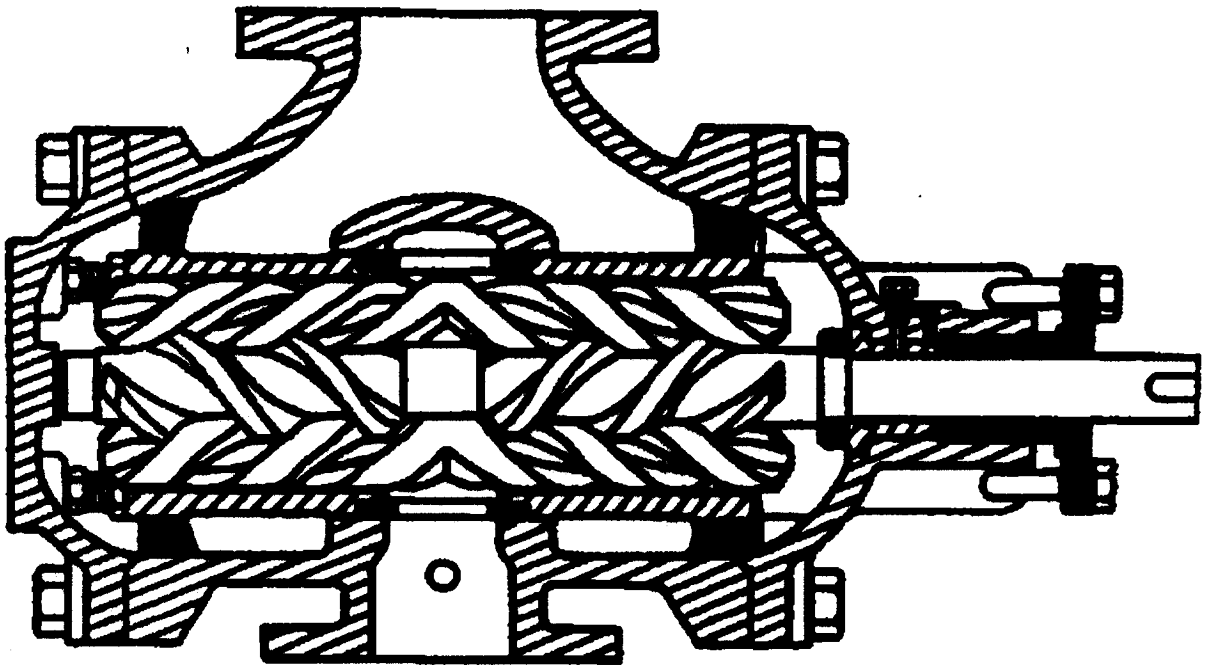
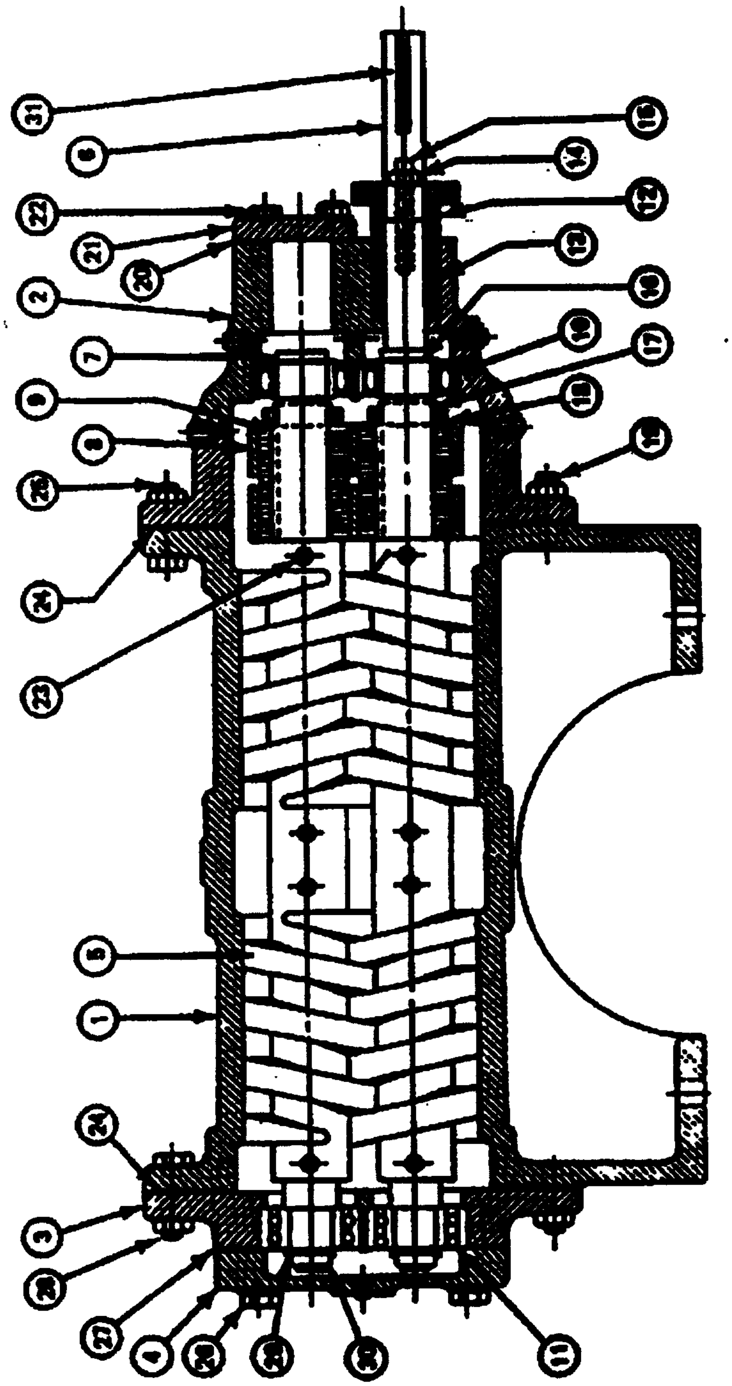


Figure 503-3-1. IMO Screw Pump without Timing Gears



NO	PART	NO	PART	NO	PART	NO	PART
1	PUMP BODY	11	BALL BRG	21	FRONT HEAD CAP	31	COUPLING KEY
2	FRONT HEAD	12	GLAND	22	FRONT CAP & HEAD BOLT		
3	REAR HEAD	13	GLAND PACKING	23	PUMPING SCREW DRIVE PIN		
4	REAR HEAD CAP	14	GLAND STUD NUT	24	BODY & HEAD GASKET		
5	PUMPING SCREW	15	GLAND STUD	25	BODY & HEAD BOLT		
6	DRIVING SHAFT	16	ROLLER BRG RETAINING RING	26	REAR CAP & HEAD BOLT		
7	DRIVEN SHAFT	17	TIMING GEAR LOCKNUT	27	REAR CAP & HEAD GASKET		
8	TIMING GEAR	18	TIMING GEAR L'WASHER	28	REAR HEAD & BODY BOLT		
9	TIMING GEAR KEY	19	FRONT HEAD & BODY STUD	29	BALL BRG L'WASHER		
10	ROLLER BRG	20	FRONT CAP & HEAD GASKET	30	BALL BRG LOCKNUT		

Figure 503-3-2. Worthington Screw Pump with Timing Gears

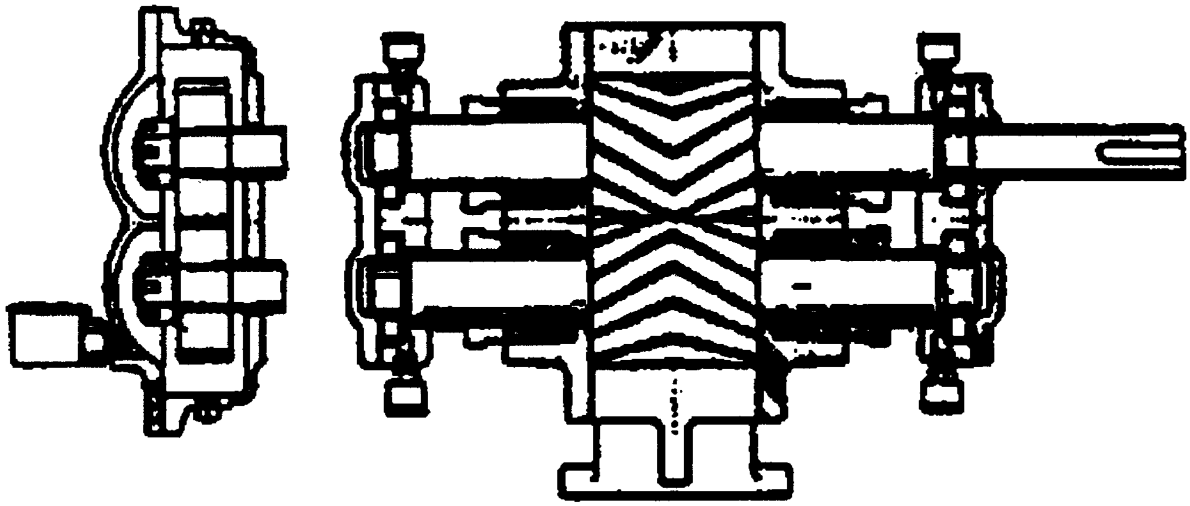


Figure 503-3-3. Rotary Pump With Herringbone Gears

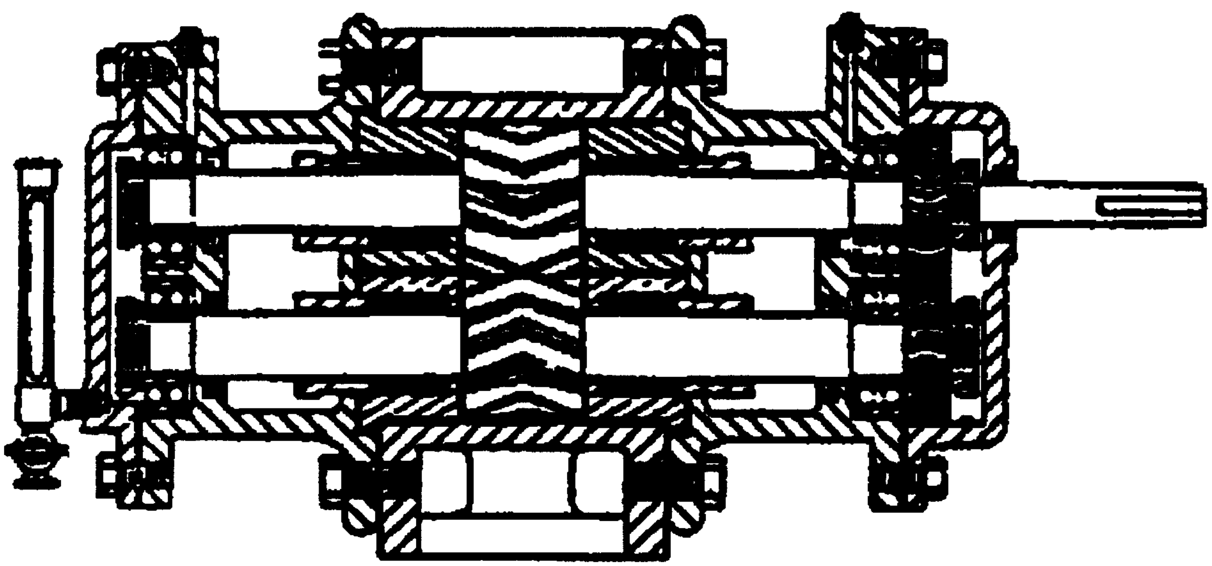


Figure 503-3-4. Gear Pump With Separate Timing Gear

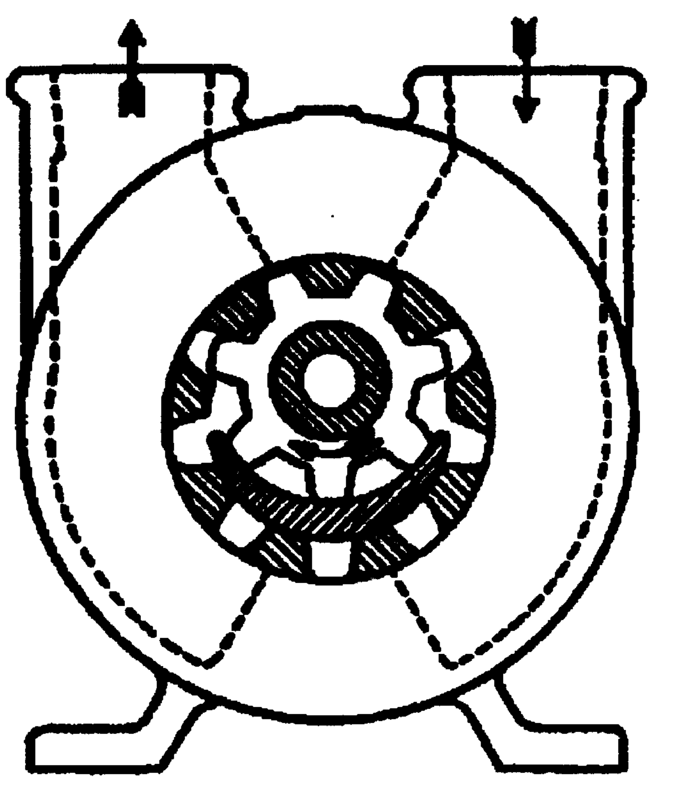


Figure 503-3-5. Rotary Pump With Internal Gears

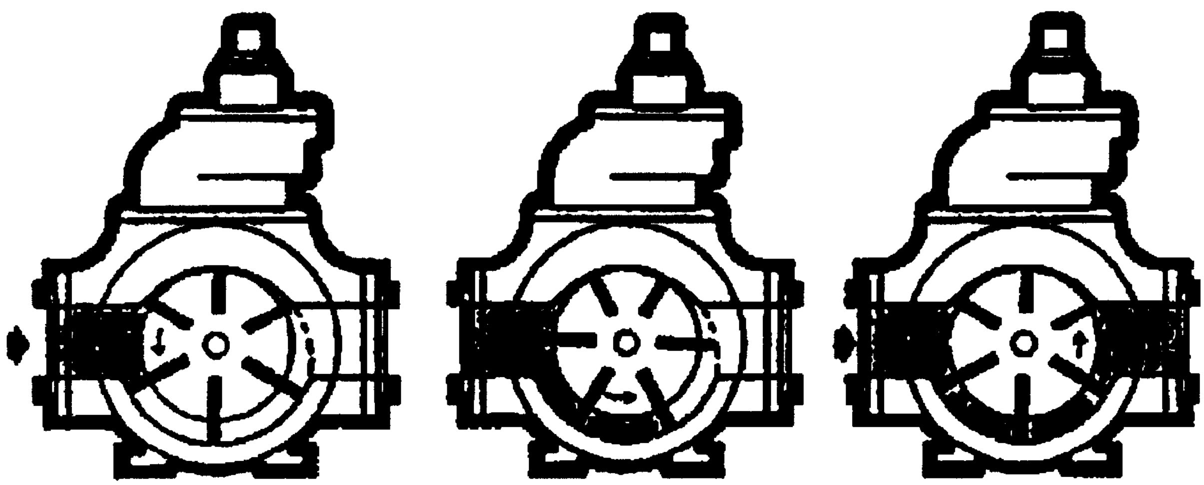


Figure 503-3-6. Rotary Pump With Sliding Vane Rotor Assemblies

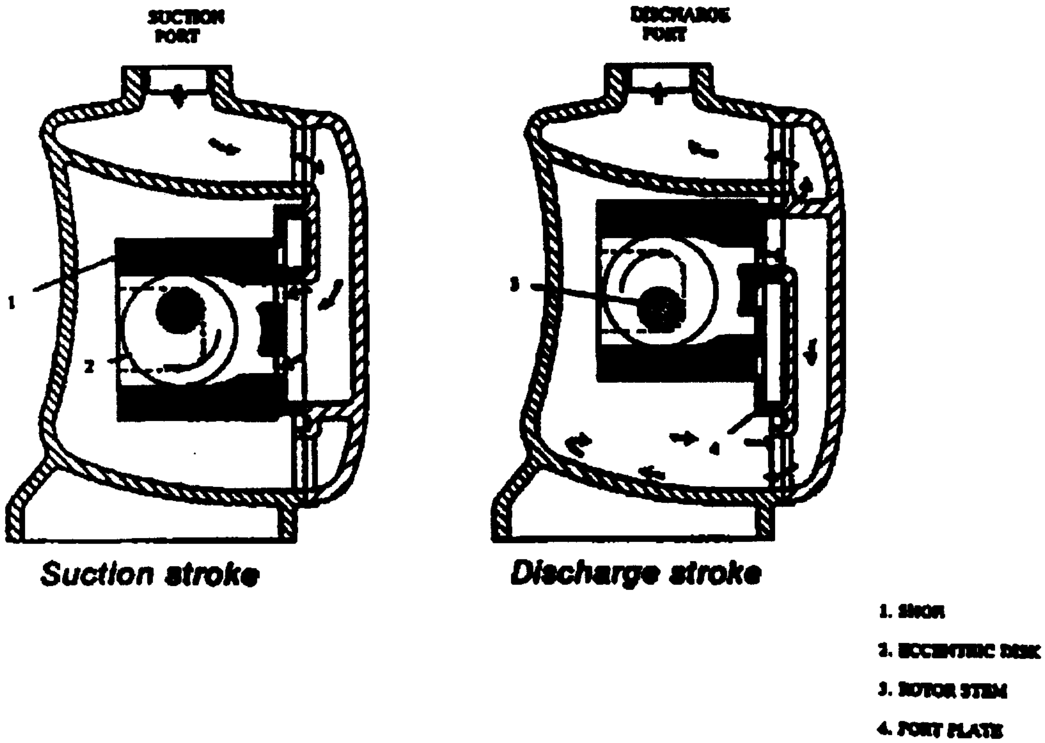


Figure 503-3-7. Rotary Pump With Sliding Shoes

503-3.4.2.2 Rotors are also classified by shaft position (horizontal, vertical, or inclined) and by types of drive and power.

503-3.4.3 SERVICE APPLICATIONS. Rotary pumps are used in the naval service for these principal applications (which are discussed in paragraph 503-3.6).

503-3.4.3.1 Fuel Services - Clean.

a. Main Fuel Service - Steam Turbine Driven Ships

b. Fuel Booster Service - Gas Turbine Driven Ships

c. Port Fuel Service - Steam Turbine Driven Ships

d. Diesel Oil Service

e. JP-5 Service

503-3.4.3.2 Fuel Services - Contaminated.

a. Fuel Stripping

b. Fuel Transfer

c. Cargo Stripping

d. JP-5 Transfer

e. JP-5 Stripping

503-3.4.3.3 Lubricating Oil Pumps.

503-3.4.3.4 Heavily Contaminated Seawater.

a. Oily Wastewater Transfer

b. Bilge Stripping

503-3.5 ROTARY PUMP CHARACTERISTICS

503-3.5.1 GENERAL. Rotary pumps are the positive displacement type, and their capacity is directly proportional to pump speed subject to capacity losses discussed in paragraphs 503-3.5.3.2 through 503-3.5.9. The rotary pump pressure developed is pressure imposed by resistance of the system to which it discharges; pressure is limited only by the pump bursting strength and power available. For this reason, relief valves are always fitted on the pump discharge. Rotary pumps are self-priming.

503-3.5.2 DISPLACEMENT. Rotary pump displacement is the volume that the rotating elements displace during each rotor shaft revolution. Displacement is independent of all operating conditions and is a theoretical capacity (assuming complete filling of the pumping spaces and no internal recirculation losses).

503-3.5.3 CAPACITY. Rotary pump capacity is the quantity of fluid actually delivered under specified conditions. Capacity is equal to the displacement times the revolutions per minute minus losses due to slip or inlet conditions. The ratio of the actual capacity to the displacement expressed in percent is known as the pump's volumetric efficiency.

503-3.5.3.1 Slip. Slip is the quantity of fluid that bypasses from discharge to suction through the internal working pump clearance. Slip varies directly with pressure and inversely with viscosity.

503-3.5.3.2 Inlet Conditions. Fluid conditions at the pump suction are important to the pump performance, and include suction pressure or lift, viscosity, operating temperature, vapor pressure, and the amount of entrained or dissolved air or gas. Capacity losses resulting from inlet conditions which do not permit complete pumping element filling are not considered to be slip.

503-3.5.4 HIGH SUCTION LIFT EFFECT. Rotary pumps in like new condition will lift oil as well as reciprocating pumps. The volumetric efficiency will drop off rapidly if the pump is required to operate on a vacuum or suction lift exceeding that for which it is designed. This is due to the effects of cavitation. Figure 503-3-8 is a representative curve showing a typical rotary pump's drop in volumetric efficiency. Different designs will display unique curves showing these same general trends. The upper curve A shows that with the pump handling viscous oil (700 SSF), the capacity is maintained well above the rated capacity of 250 gpm at 25 in.Hg. When the pump is handling the same oil at a lower viscosity (higher temperature - 70 SSF), the lower capacity curve B drops off abruptly at more than 19 to 20 in. Hg suction lift. This capacity reduction is caused in part by increased slip but to a greater extent by oil deaeration and vaporization.

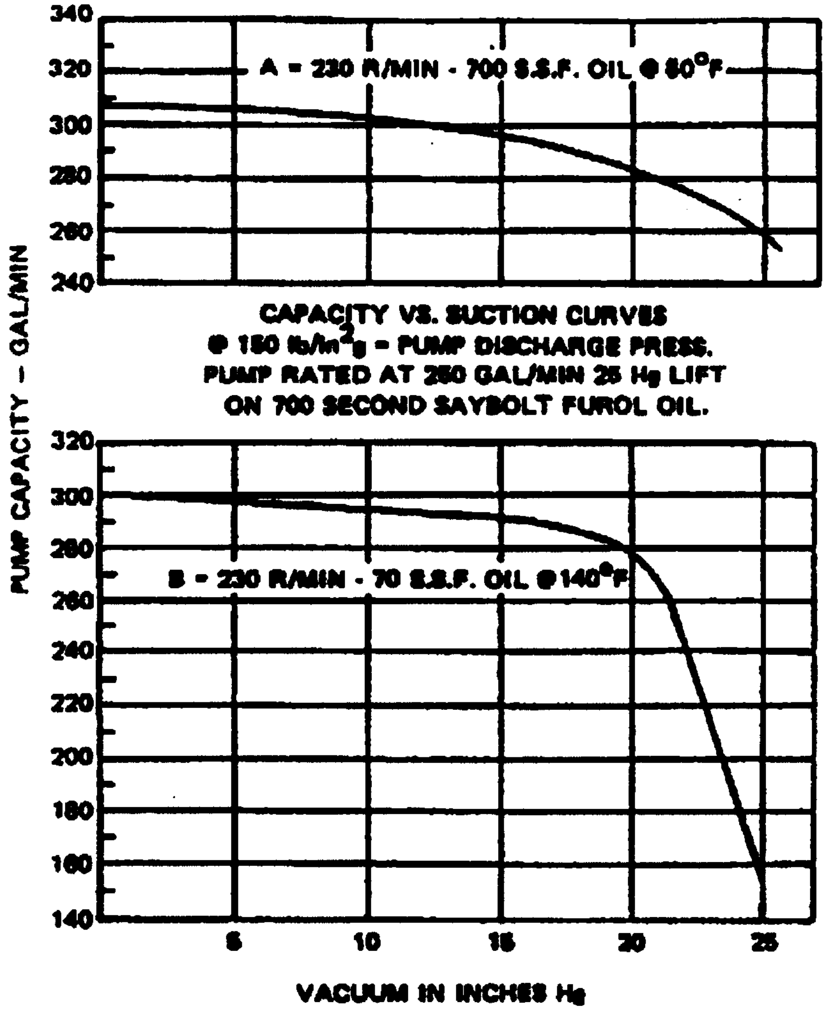


Figure 503-3-8. Contrasting Capacity Curves

503-3.5.5 ENTRAINED GAS EFFECT. Most liquids are susceptible to air or gas entrainment (the trapping of bubbles in the liquid). Air entrainment is common in systems where recirculation occurs and the liquid is exposed to air through either mechanical agitation, leaks, or improperly located drain lines. Entrained air or gas in liquids handled by rotary pumps has an effect on pump performance, both mechanically and hydraulically, especially where negative inlet pressure (suction lift condition) exists. When the inlet pressure is below atmospheric pressure, entrained gas in the fluid will expand and take up a larger part of the pump displacement, thereby reducing its liquid capacity. The effect of entrained gas on liquid displacement is shown in Figure 503-3-9. If the entrained air or gases is a large percentage of the volume handled, there may be noise and vibration, loss of liquid capacity, and pressure pulsations. The pulsation frequency depends on the speed and number of closures in the rotor element during each revolution.

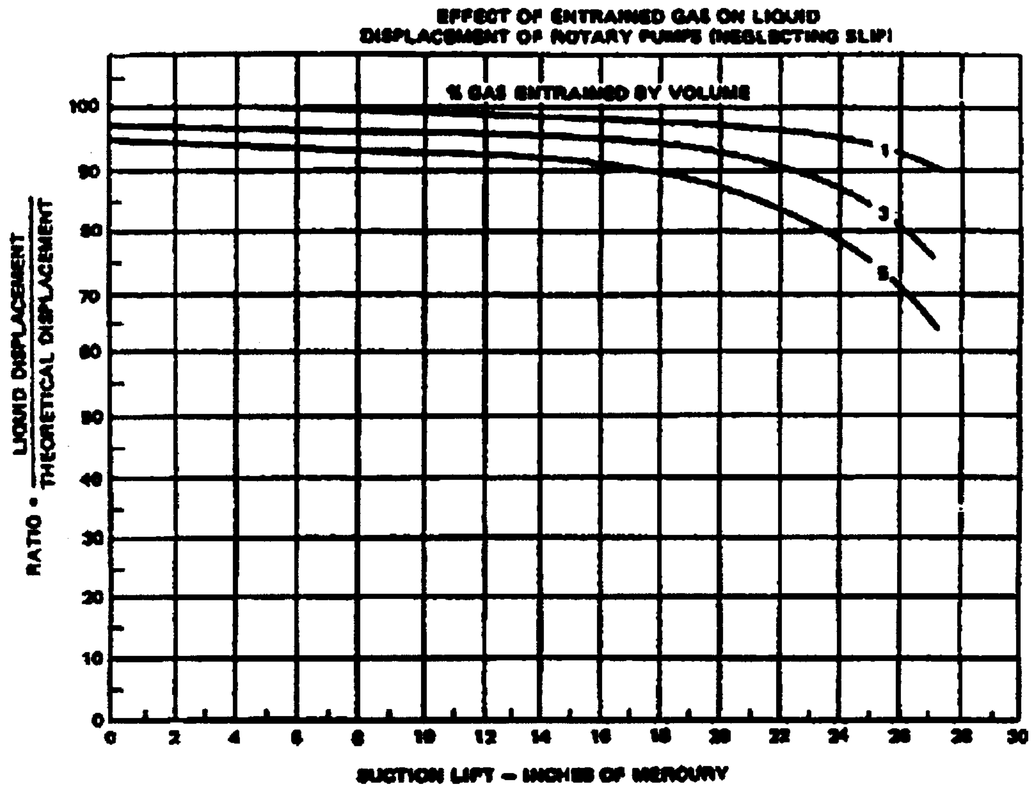


Figure 503-3-9. Effect of Entrained Gas on Liquid Displacement

503-3.5.6 DISSOLVED GAS EFFECT Many liquids contain dissolved air or gas in the solution. The solubility of air or gas in liquids varies with the type of liquid and the pressure to which it is subjected. For example, lube oil at atmospheric pressure and temperature may contain up to 10 percent of dissolved air by volume. Dissolved air or gas in liquids handled by rotary pumps has a similar effect on pump performance, but not as significant, as entrained air or gas as described in paragraph 503-3.5.5. The effect of dissolved gas on liquid displacement is illustrated in Figure 503-3-10.

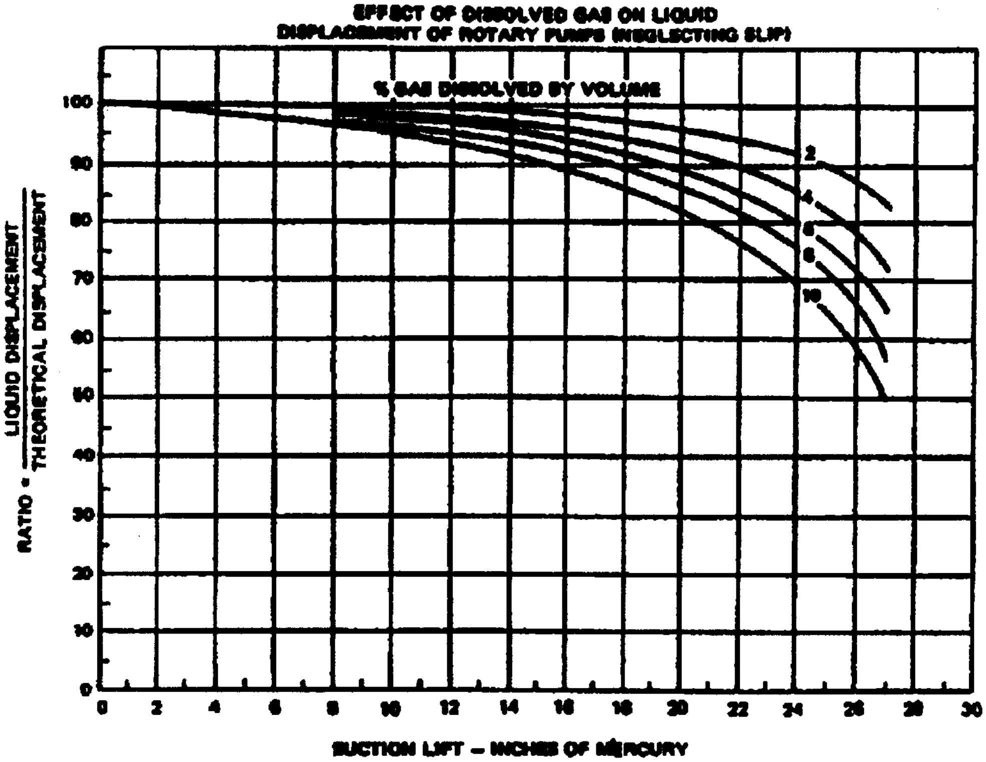


Figure 503-3-10. Effect of Dissolved Gas on Liquid Displacement

503-3.5.7 VISCOSITY EFFECT. Rotary pumps are suitable for handling fluids over a wide range of viscosities. The power required increases with viscosity because of increased friction within the pump. The pump speed should be reduced when handling increased viscosity to allow the rotors time to fill. Extensive tests have been made on the maximum rubbing or pitch line speed for different oils, and the resulting limitations are incorporated into specifications for rotary pumps for naval service.

503-3.5.8 BEARINGS. Rotary pump bearings are classified as either external or internal. External bearings are separated from the fluid pumped by shaft packing or mechanical seals. Since fuel (diesel) has low viscosity, seals in pumps in fuel service must be carefully installed to prevent leakage (see Section 5). Internal bearings are located between the rotor elements and the packing and depend on the pumped fluid for lubrication. Internal bearings are not suitable for pumps handling fluids containing abrasives or having low viscosity (lacking lubricity).

503-3.5.9 GLAND SEALING. If pumps are required to take suction at lower than atmospheric pressure and have a packed stuffing box, it is important that the shaft stuffing boxes be fitted with a lantern ring and sealed by the pumped fluid (see Section 5). These precautions prevent entrance of air into the pump. Stuffing box gland sealing fluid is taken from the pump discharge.

503-3.6 APPLICATIONS

503-3.6.1 FUEL SERVICES - CLEAN. Clean fuel services have a viscosity range from 32 SSU to 1500 SSU and include the following:

503-3.6.1.1 Main Fuel Service - Steam Turbine Driven Ships. For boiler fuel service, screw-type pumps are extensively used in naval service. Pumps for boiler fuel service are designed for suction conditions up to 10 inches, distillate fuel and discharge pressures of 350 or 450 lb/in^2 g, depending on the burner system of the particular ship on which they are installed.

503-3.6.1.2 Fuel Booster Service - Steam Turbine Driven Ships. Fuel booster pumps operate in severe conditions because they pump oil through long suction lines that may have pockets or traps. The oil may have high viscosity resulting in high friction loss with high net suction lift at the pump inlet. Therefore such pumps are usually driven by multispeed motors to increase capacity and avoid operating at a too high a suction lift with cold oil. IMO pumps (Figure 503-3-1) are widely used for fuel booster service. Other pumps used include Warren screw pumps with timing gears (Figure 503-3-11) and Blackmer sliding vane pumps (Figure 503-3-6).

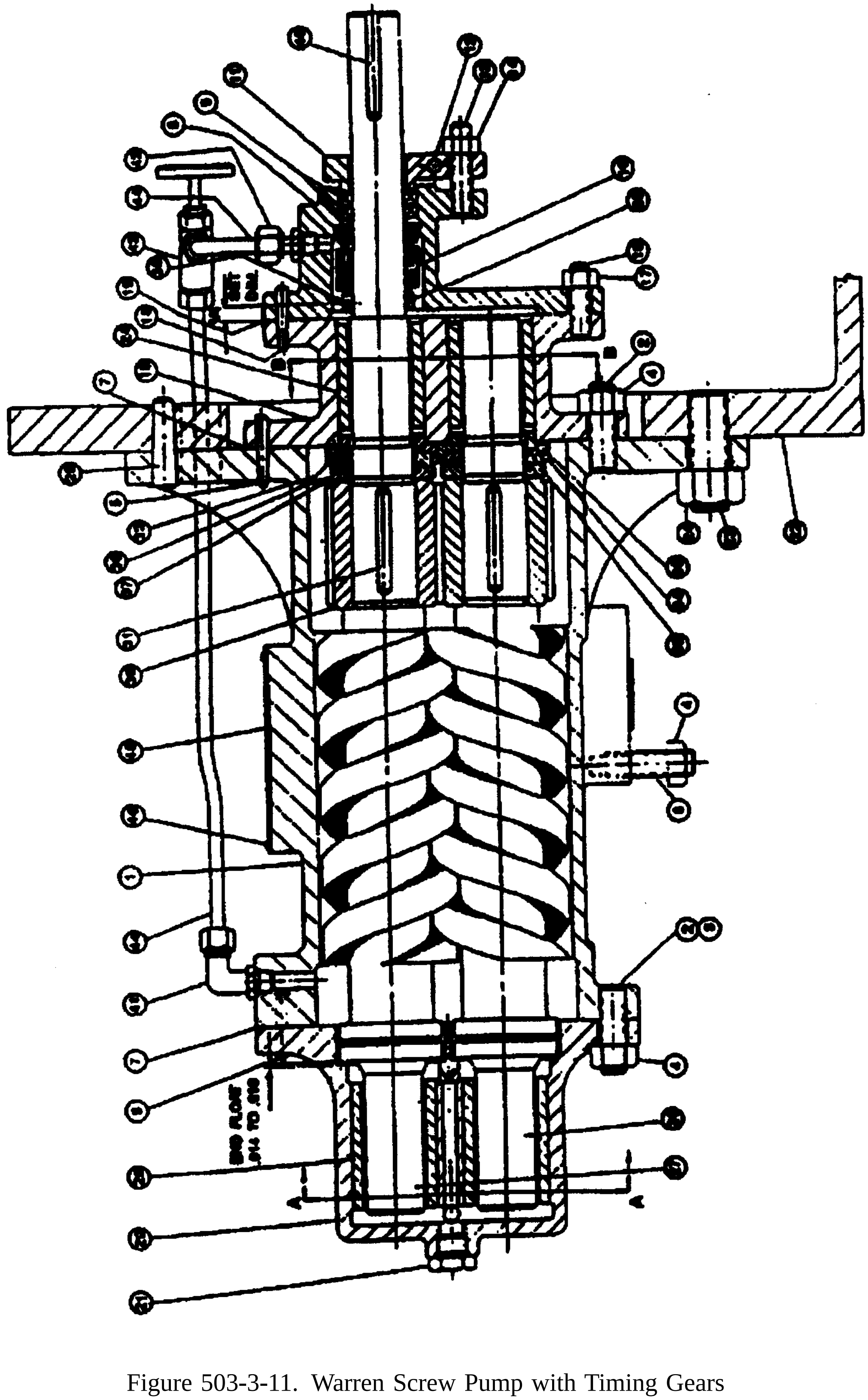


Figure 503-3-11. Warren Screw Pump with Timing Gears

CAUTION

IMO pumps may be susceptible to fuel suction loss damage or entrapped solids. The suction valve should never be closed when the pump prime mover is rotating. To prevent excessive wear or pump failure, the fuel should be checked for solid contaminants.

503-3.6.1.2.1 With proper care, IMO pumps are highly reliable in service. Carry out an operational inspection to diagnose a failed fuel service pump and before an industrial activity period.

CAUTION

Treat a motor-driven fuel service pump that cannot satisfy rated boiler demand as a casualty. Also treat as a casualty any turbine-driven fuel service pump that requires maximum steam chest pressure and that constantly operates at maximum governor speed and cannot supply rated boiler demand.

503-3.6.1.2.2 If the pump is diagnosed as a failure or is leaking, the pump should be overhauled, including replacement of bearings, gaskets, seals, and O-rings.

503-3.6.1.3 Port Fuel Service - Steam Turbine Driven Ships. The majority of ships, including those of latest design, are equipped with constant delivery pumps, similar to main fuel service pumps. These pumps are driven by two-speed motors, and pump capacities are further adjusted by a bypass valve which returns unused oil from the burner line to the pump suction.

503-3.6.1.4 Diesel Oil Service. Diesel oil service is not difficult, and most pumps described in preceding paragraphs are suitable. For space and weight economy, the IMO screw pump (Figure 503-3-1), or those pumps shown in Figure 503-3-3, Figure 503-3-4, Figure 503-3-6, and Figure 503-3-10 are usually used for diesel oil service.

503-3.6.1.5 JP-5 Service. JP-5 service pumps take suction from JP-5 service tanks and discharge to the fueling stations. Typically, screw pumps without timing gears (Figure 503-3-1), sliding vane pumps (Figure 503-3-6), or screw pumps with timing gears (Figure 503-3-11) are used for this service.

503-3.6.2 FUEL SERVICES - CONTAMINATED. Contaminated fuel services have a viscosity range from 32 SSU to 4000 SSU and include the following:

503-3.6.2.1 Fuel Stripping Pumps. Fuel stripping pumps must handle mixtures of fuel, sludge, seawater, and sediment that are found on the bottom of fuel tanks. These pumps are usually sliding vane pumps or screw pumps with timed rotors which prevent metal-to-metal rotor contact, a necessary feature for pumps handling abrasive fluids such as encountered in this application. When sliding vane pumps are reassembled, the technical manual should be followed for procedures that will prevent excessive vane wear resulting from improper placement of the vanes in their slots.

503-3.6.2.2 Fuel Transfer. Fuel transfer pumps take suction from fuel storage tanks and discharge to other fuel storage tanks. Typically, screw pumps without timing gears (Figure 503-3-1), sliding vane pumps (Figure 503-3-6), or screw pumps with timing gears (Figure 503-3-11) are used for this service.

503-3.6.2.3 Cargo Stripping. For cargo stripping service (diesel fuel or JP-5), pumps must operate in a suction lift condition or act as continuous priming pumps for centrifugal main cargo pumps. When the fluid level in the tank lowers, pumps shown in Figure 503-3-4 and Figure 503-3-6 are used.

503-3.6.2.4 JP-5 Transfer. JP-5 transfer pumps take suction from storage tanks and discharge to service tanks, fill connections, and the fill and transfer system. Typically, screw pumps without timing gears (Figure 503-3-1), sliding vane pumps (Figure 503-3-6), or screw pumps with timing gears (Figure 503-3-11) are used for this service.

503-3.6.2.5 JP-5 Stripping. JP-5 stripping pumps take suction from storage and service tanks and discharge to waste oil drain tanks. Typically, screw pumps without timing gears (Figure 503-3-1), sliding vane pumps (Figure 503-3-6), sliding shoe pumps (Figure 503-3-7), or screw pumps with timing gears (Figure 503-3-11) are used for this service.

503-3.6.3 LUBRICATING OIL PUMPS. The main lubricating oil pumps are typically IMO vertical screw pumps without timing gears (Figure 503-3-1) or Warren vertical screw pumps with timing gears (Figure 503-3-11). The main pumps may be steam-turbine driven, motor driven, or reduction gear driven. The standby and emergency lube oil pumps are of the same design but are motor driven. Lubricating oil pumps are subjected to severe operating conditions because of entrained air in the lubricating oil. Constant speed, motor-driven, lubricating oil pumps (which must run at maximum capacity regardless of the system operating conditions or demands) are especially subjected to these conditions. Pumping these air-oil mixtures may result in insufficient oil supply to the main reduction gear and cause pulsating discharge pressures, pump and pipe vibration and, in extreme cases, line breakage. Actions taken to reduce the pulsation effect have included:

a. Reduction of suction friction by increasing suction line size.

b. Improvement of entrance conditions in the pump suction.

c. Elimination of dead-end relief valve lines.

503-3.6.4 HEAVILY CONTAMINATED SEAWATER. Heavily contaminated seawater has a viscosity range from 32 SSU to 4000 SSU and includes the following services:

503-3.6.4.1 Oily Wastewater Transfer. Oily wastewater transfer pumps take suction from the oily wastewater main and discharge to the oily wastewater holding tank. Typically, sliding vane pumps (Figure 503-3-6) or sliding shoe pumps (Figure 503-3-7) are used for this service.

503-3.6.4.2 Bilge Stripping. Bilge stripping pumps take suction from the bilges and discharge to the waste oil drain tanks. Typically, sliding vane pumps (Figure 503-3-6) or sliding shoe pumps (Figure 503-3-7) are used for this service.

503-3.6.5 AFFF SERVICE. AFFF pumps take suction from AFFF service tanks and discharge to the AFFF service system. Typically, sliding vane pumps (Figure 503-3-6) are used for this service.

503-3.7 ROTARY PUMP OPERATION

503-3.7.1 Refer to the Engineering Operation Sequence System (EOSS) or the pump technical manual for specific rotary pump preoperation checks, starting procedures, and stopping and securing procedures. Instructions for all pumps cannot be covered here because of the diverse types, designs, and applications in the fleet. The applicable technical manual should be studied before any attempt is made to operate or service the unit. The following general caution should be observed.

CAUTION

A rotary pump is a positive displacement pump and must not be started against a closed or restricted discharge.

503-3.8 TROUBLESHOOTING ROTARY PUMPS

503-3.8.1 NO LIQUID DELIVERED. If the pump fails to discharge fluid when first started, stop the pump. The cause may be one or more of the following:

a. Pump is not primed.

b. Suction lift is too high. Check the suction with a vacuum gage at pump suction; the fluid may be vaporizing.

c. Incorrect direction of rotation on motor-driven unit.

d. Air leaks in pump and suction lines.

e. Obstruction in the pump suction. If equipped with a suction strainer or filter, check to see if the strainer or filter element needs to be cleaned or replaced.

f. Leak in the bypass relief valve; it may be lifting or held off-seat by foreign matter.

g. Air is not completely vented.

503-3.8.2 LOW CAPACITY. If the pump discharges but does not deliver sufficient capacity, the cause may be one or more of the following:

a. Air leaks in suction or through pump stuffing boxes.

b. Pump speed is too low.

c. Suction lift is too high.

d. Suction strainer if fitted, may be too small or clogged.

e. End of the suction pipe is not sufficiently submerged into fluid supply.

f. Pump is damaged, badly worn, or pump mechanical seal or packing is defective.

g. Relief valve improperly adjusted or held off-seat.

h. Bypass line to suction is partly open.

503-3.8.3 LOSS OF SUCTION. If the pump delivers fluid for a while and then loses its suction or fails to deliver, the cause may be:

a. Leaky suction lines.

b. Suction lift too high, causing fluid to vaporize.

c. Air or gas evolves into suction line pockets.

503-3.8.4 EXCESSIVE POWER REQUIRED. If the pump draws excessive power, the cause may be:

a. Pump speed is too high.

b. Fluid is heavier or more viscous than specified. Reduce the pump speed.

c. Suction or discharge lines are obstructed. Check pressures developed by the pump. If neither obstructions nor partly closed valves are evident, record complete data for pressures, pump speed, viscosity, and temperature of fluid with a dimensioned sketch of the system in use. Reduce the pump speed to decrease load.

d. Mechanical defects such as a bent shaft, rotor binding, stuffing box packing too tight, foundation misalignment, casing distortion caused by piping connections, or interferences within pump.

503-3.8.5 VIBRATION OR NOISE. If the pump is noisy or vibrates, check for the following:

a. Air or gas in the fluid.

b. Air leaking into suction.

c. Fluid vaporizing in suction (reduce suction lift).

d. Mechanical defects such as misalignment, rotor interference, high spots rubbing, bearing failure, or a bent shaft.

e. Relief valve chattering.

f. Rotor out of balance.

503-3.8.6 PUMP WEARS RAPIDLY. If pump wears rapidly, the cause could be:

a. Fluid contains sand, other abrasive, or foreign matter.

b. Misalignment.

c. Pump operating at greater-than-rated pressure.

d. Operation with fluid of lower than specified viscosity.

e. The pumped fluid is corrosive.

f. Pump has run dry or is pumping with insufficient fluid.

503-3.8.7 SHORT LIFE OF PACKING AND SEALS.

a. Speed too high.

b. Misalignment.
c. Bent shaft.
d. Interference between rotating and stationary parts.
e. Worn journal bearings.
f. Worn or scored shaft sleeves at packing.
g. Packing or seals installed wrong.
h. Wrong type of packing.
i. Rotor out of balance.
j. Packing gland too tight preventing lubrication of packing.
k. Liquid contains dirt and grit causing scoring.

503-3.8.8 SHORT LIFE OF BEARINGS.

a. Speed too high.
b. Misalignment.
c. Bent shaft.
d. Interference between rotating and stationary parts.
e. Rotor out of balance.
f. Mechanical failure inside pump causes excessive thrust.
g. Excessive bearing temperature.
h. Bearing incorrectly installed.

503-3.8.9 OVERHEATING AND SEIZING.

a. Speed too high.
b. Misalignment.
c. Bent shaft.
d. Interference between rotating and stationary parts.
e. Worn journal bearings.
f. Packing installed wrong.
g. Wrong type of packing.
h. Rotor out of balance.
i. Packing gland too tight preventing lubrication of packing.
j. Mechanical failure inside pump causes excessive thrust.
k. Excessive bearing temperature.
l. Bearings incorrectly installed.

m. Dirt in bearings.

503-3.8.10 SUCTION LINE VAPOR LOCK. When a pump is in good condition and builds a good vacuum on suction but does not build discharge pressure after all other possible problems are corrected, vapor lock in suction piping should be investigated. Investigation should be initiated particularly in long lengths of fuel suction piping and especially after new oil cargo has been received or the oil has been heated. Shift suction to another tank or group of tanks nearer the pump; usually the pump will build pressure immediately. If no nearer tank is available, build air pressure in the tank, taking particular care that the tank pressure does not exceed limits set by General Specifications for Shipbuilding and ships' information books.

503-3.8.10.1 The lighter hydrocarbons such as gasoline have much higher vapor pressure than heavier fuels at the same temperature. If heavy pounding of the pump occurs when pumping fuel, the vacuum on the suction side of the pump usually is excessively high or the temperature of the fuel is high for the type of fuel being pumped. These factors cause partial vaporization in the suction line or pump casing.

503-3.8.10.2 In measuring suction lift, first measure absolute suction pressure available. Ensure that the resulting absolute suction pressure is greater than atmospheric pressure minus the vapor pressure at the pumping temperature plus 2 lb/in^2 (approximately 4.1 in.Hg). For example: a pump which is pumping gasoline with a vapor pressure of 11 lb/in^2 absolute should have an absolute suction pressure available greater than

14.7-(11 + 2) = 1.7 lb/in^2 or a suction lift less than 3.5 in.Hg (conversion from lb/in^2 to in.Hg):

1.7 lb/in^2 x 2.03in.Hg / lb/in^2 = 3.46 in.Hg

503-3.8.10.3 Vapor lock is most apt to occur in pockets where the suction line overpasses other piping or ship structure, particularly in the pump proximity. It will be difficult for the pump operator to determine whether malfunction resulting in noise and pounding is caused by deaeration or vaporization; however, decreasing the suction lift by reducing pump speed, for example, will alleviate vapor lock. If the pump suction line has a vent line installed, the vapor from the suction can be removed by opening the vent valve and then closing it once the vapor is released.

503-3.9 MAINTENANCE

503-3.9.1 GENERAL. Information provided here supplements preventive and corrective PMS maintenance procedures. Maintenance procedures shall be as specified on MRCs. If inconsistencies are noted, submit OPNAV 4700/7, PMS Technical Feedback Report (TFBR).

503-3.9.2 USING TECHNICAL MANUALS. Instructions contained in pump technical manuals should be followed in rotary pump maintenance. Instructions in this chapter are of a general nature and are intended to supplement equipment technical manuals.

503-3.9.3 SUCTION GAGES. All fuel pumps should have compound gages installed at pump suction manifolds to allow determination of the suction lift vacuum.

503-3.9.4 WEARING PLATES AND LINERS. Both the design clearance and the maximum allowable clearance between pump rotors and casing wearing plates and cylinder liners are shown on manufacturers' drawings and in the equipment technical manual. When actual clearance exceeds allowable limits, parts should be renewed in accordance with PMS and the technical manual requirements. Failure to renew parts and restore design clearance when allowable clearances are exceeded will result in pump capacity and efficiency decrease.

503-3.9.4.1 The allowable clearance for low pressure, low suction lift pumps (for example, lubricating oil, fuel booster, and tank drain pumps) is larger than the allowable clearance for medium and high pressure pumps (for example, boiler fuel service pumps). As the pressure drop across the clearance space increases, closer tolerances must be maintained to prevent degraded pump performance. Similarly, as suction lift increases, the allowable clearances must be tighter so that the pump will be able to pull a vacuum and lift the fluid into the pump. Increased pressures and internal clearances result in a greater loss of pump capacity due to increased pump internal fluid recirculation or slip.

503-3.9.5 THRUST BEARINGS. Information concerning thrust bearings is in paragraph 503-2.8.8.

503-3.9.6 TIMING GEARS. Pump types shown in Figure 503-3-2, Figure 503-3-4, and Figure 503-3-11 have timing (or synchronizing) gears which are fitted to rotor shafts to maintain correct clearances between the two pumping rotors during operation. To maintain correct clearances, gears must be locked to the rotor shaft in correct position to maintain the clearance between rotor elements as shafts make a complete revolution; therefore, no lost motion is permissible adjacent to keys or pins holding rotors and gears in position on the shafts.

503-3.9.7 MOTORS AND CONTROLLERS. Instructions in **NSTM Chapter 302, Electric Motors and Controllers** , should be followed for motor-driven unit maintenance.

503-3.9.8 TURBINES. Instructions in **NSTM Chapter 502, Auxiliary Steam Turbines** , should be followed for turbine-driven unit maintenance.

503-3.9.9 PUMP PRESSURE-REGULATING GOVERNORS. Boiler fuel service, lubricating oil pumps, and some fuel booster pumps are fitted with adjustable constant-pressure- type pump governors in addition to turbine governors described in paragraph 503-2.9 and **NSTM Chapter 502, Auxiliary Steam Turbines** .

503-3.9.10 TESTS AND INSPECTIONS. Rotary pumps should be tested or inspected periodically in accordance with requirements. Information in paragraphs 503-3.9.10.1 through 503-3.9.10.5 is intended to be used as a general guide and is not inclusive of all tests or inspections required by PMS.

503-3.9.10.1 The most frequent PMS routine is to test-operate idle pumps under normal conditions and inspect for mechanical seal leakage. Operate by steam or power as applicable. If power is not available, move the pump manually.

503-3.9.10.2 Periodically, in accordance with PMS:

1. Lift all relief valves by water or oil, as appropriate.
2. Check thrust position of pump rotor.
3. Sound and set up as necessary all foundation bolts and secure all foundation dowel pins.

503-3.9.10.3 Periodically, in accordance with PMS for the specific pump:

1. Check bearing clearances by leads or crown thickness measurements.

CAUTION

Do not close the suction valve completely because this may result in damage to the pump rotating elements and mechanical seal. Lubricating oil service pump suction should be at least 6 in.Hg.

2. Check wear of internal parts by slowly throttling suction valve with pump running at normal speed.

503-3.9.10.4 If the pump will not pull the required vacuum, the pump should be opened, clearances measured, and necessary steps taken either by renewal of parts, adjustment of rotors or taking a cut off the casing cover, as applicable, to restore designed clearances. In making this test, ensure that the pump is filled with oil before throttling the suction valve.

503-3.9.10.5 For regular rotary pump overhaul, periodically:

1. Open pump and reduction gear casings; inspect and clean.
2. Check clearances of all wearing plates and liners, casing throat bushings, rotors, casing liners and bushings and renew parts as necessary.
3. Examine all pump rotors, shafts, bearings, timing gears, keys, and reduction gears, particularly worms and worm wheels.

NOTE

These tests and inspections are the minimum necessary to ensure safe and reliable equipment operation. Low discharge pressure or other manifestations of improper operation indicate the need for frequent or extensive tests and inspections. For tests and inspections of turbines, see **NSTM Chapter 502, Auxiliary Steam Turbines** .

503-3.10 REPAIRS

CAUTION

Only qualified personnel should attempt repair of these pumps.

503-3.10.1 ASSEMBLY DRAWINGS. When repairing or making an interior pump examination, it is essential that all drawings and available dimensional data be at hand. Frequently, alterations occur in such important dimensions as bridge gage readings, clearance between rotors and casing wearing plates and liners, and shaft seal or gland adjustments, resulting in poor operation. This problem will persist in spite of other major repairs until the real cause is corrected. For these reasons, unauthorized field conversion or parts substitution should be avoided.

503-3.10.2 RENEWING WEARING PLATES AND LINERS. Whenever the pump casing is opened, the clearance between casing liners and plates and various parts of the rotors and shaft should be measured to determine if excessive wear has taken place and if renewal is necessary. If bearings are worn excessively, it is reasonable to expect that liner replacement is necessary. Liners should not be renewed unless worn pump bearings are restored to their original readings. The required bearing oil clearance is usually given on the manufacturers' plans. In the absence of this data, the table of tolerances and clearances provided in Table 503-2-2 should be followed.

SECTION 4.
RECIPROCATING PUMPS

503-4.1 RECIPROCATING PUMP SAFETY PRECAUTIONS

503-4.1.1 Adherence to the following prescribed precautionary practices will help ensure safe operation of reciprocating pumps.

a. Never use a jacking bar to start a pump while the steam valve to the pump is open.

b. Except in an emergency, boiler feed pumps shall not be used for purposes other than those connected with the service of the boilers or use of feedwater.

c. Before opening a steam cylinder or steam valve gear ensure that drains are open and that steam and exhaust root valves are wired closed and tagged DO NOT OPEN.

d. Before opening the water cylinder or valve chest of a pump handling water at a temperature in excess of 48.9° C (120° F), ensure that suction and discharge valves are wired closed and cylinder and valve chests are drained.

e. Always open steam cylinder drain valves when the pump is shut down and leave them open until the pump is again started and cleared of condensation.

503-4.2 TYPES OF RECIPROCATING PUMPS

503-4.2.1 Reciprocating pumps are positive displacement pumps that are divided into three general types: steam, power, and controlled volume.

503-4.2.2 A further breakdown of the different types is shown in Figure 503-4-1. The construction of a pump is usually divided into two parts: liquid end and drive end. The liquid end is the end of the pump that actually pumps the liquid. The drive end of a power pump contains the necessary mechanism to convert rotary input energy into reciprocating linear pumping energy. The drive end of a steam pump contains the steam piston that provides the force to drive the liquid end piston.

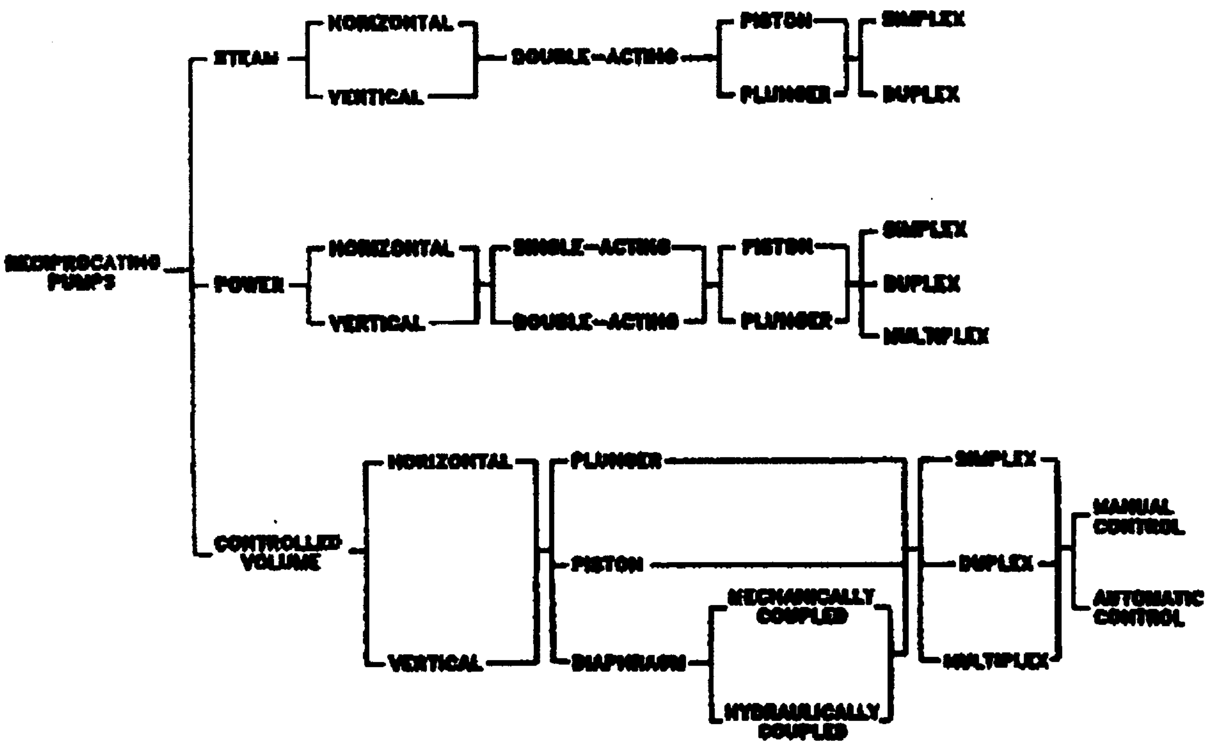


Figure 503-4-1. Types of Reciprocating Pumps

503-4.3 RECIPROCATING PUMP TERMINOLOGY

503-4.3.1 The following terminology applies to reciprocating pumps:

a. Steam pump - A steam pump is a reciprocating pump driven by a reciprocating steam engine which is built as an integral part of the pump assembly. Since there is no need to convert rotary motion to reciprocating motion, the pump is often referred to as direct-acting. Although steam is referred to as the driving medium, gases such as air can also be used as the motive force. (See Figure 503-4-4 for basic principles of steam pump operation.)

b. Power pump - A power pump is a reciprocating pump driven by power from an outside source applied to the crankshaft of the pump.

c. Controlled volume pump - A controlled volume pump is a reciprocating power pump used to accurately displace a predetermined volume of fluid in a specified time period that is driven from an outside power source. The pump assembly includes a mechanism for changing the effective displacement. The pump is often referred to as a metering pump, proportioning or chemical injection pump.

d. Horizontal pump - The axial centerline of the cylinder is horizontal.

e. Vertical pump - The axial centerline of the cylinder is vertical.

f. Single-acting pump - Liquid is discharged only during the forward stroke of the plunger or piston, that is, during one-half revolution of the crank.

g. Double-acting pump - Liquid is discharged during both the forward and return strokes of the plunger or piston, that is, discharge takes place during the entire crank revolution.

h. Piston pump - A pump whose liquid end contains one or more pistons which are attached to a reciprocating rod. A piston is a solid cylinder or disk that fits snugly into a larger cylinder. The reciprocating rod fits in a hole in the piston and the piston is positively attached to the rod (see Figure 503-4-2). The piston is capable of exerting a force upon a liquid within the liquid cylinder. A piston usually has grooves for containing rings which seal against the cylinder or cylinder liner.

i. Plunger pump - A pump whose liquid end contains one or more reciprocating rods or plungers typically of a smaller diameter than a piston (see Figure 503-4-3). The rod or plunger is capable of exerting a force upon a liquid within the liquid chamber. Sealing rings for a plunger are stationary with the plunger sliding within the rings.

j. Simplex pump - A pump that contains one piston or its equivalent single or double acting plungers.

k. Duplex pump - A pump that contains two pistons or its equivalent single or double acting plungers.

l. Multiplex pump - A pump that contains more than two pistons or its equivalent single or double acting plungers.

m. Stuffing box - A cylindrical cavity through which the plunger or piston rod reciprocates. Packing is used to control leakage between the plunger or piston rod and the pump housing.

n. Valve assembly - Usually consists of a seal, valve, spring, and spring retainer. It allows liquid to enter and leave each pumping chamber. A suction valve allows liquid to enter the pumping chamber while the plunger or piston is being retracted. The suction valve closes during the power or compression portion of the stroke. The discharge valve allows the liquid to leave the pumping chamber during the power or compression portion of the stroke. The discharge valve closes during the suction portion of the stroke. Each pumping chamber has one or more suction and discharge valve(s).

o. Pump efficiency - The pump power output divided by the pump power input. This number will always be less than 1 because of losses due to friction, slip, etc.

p. Slip - The loss of capacity, expressed as a fraction or percent of displacement, due to leaks past the valves and past double-acting pistons. Slip does not include fluid compressibility or leaks from the liquid end.

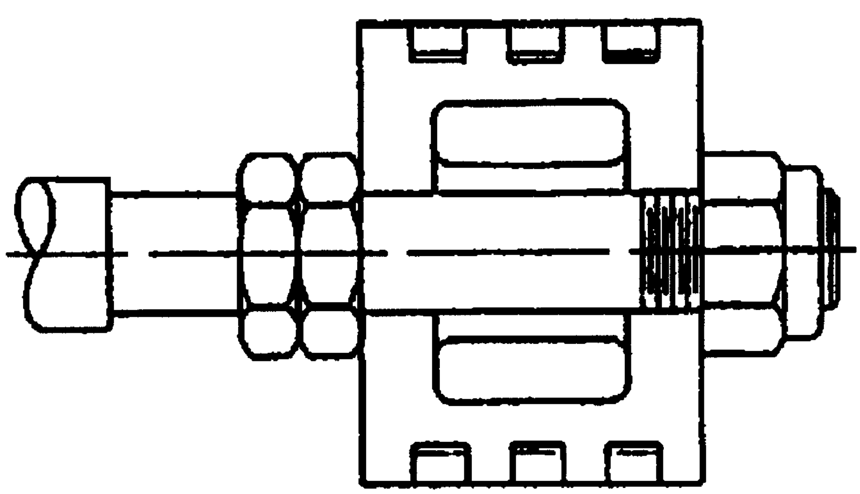


Figure 503-4-2. Individual Ring Piston

Figure 503-4-3. Plunger

503-4.4 RECIPROCATING PUMP CHARACTERISTICS

503-4.4.1 Reciprocating pumps are positive displacement units that discharge a definite quantity of liquid during piston or plunger movement through the stroke distance. However, not all the liquid may reach the discharge pipe; leaks or bypass arrangements may prevent this. Without these leaks or bypass arrangements, the volume of liquid displaced during one stroke of the piston or plunger equals the product of the piston or plunger area and the stroke length.

503-4.4.2 When the piston or plunger has reached its maximum travel in one direction, a method of reversing the piston or plunger direction is required. In the direct-acting steam pump, the piston or plunger direction is reversed by the steam valves and valve gear (actuating mechanism); in power pumps, piston or plunger direction is reversed by the crank and connecting rods. In controlled volume pumps, various mechanisms such as eccentric, cam or crank are used to translate rotary motion into reciprocating motion.

503-4.5 STEAM PUMPS

503-4.5.1 STEAM PUMP CHARACTERISTICS. The following characteristics are used to identify direct-acting steam pumps and are typically found on the pump nameplate:

a. Steam cylinder diameter.

b. Liquid cylinder diameter.

c. Stroke length.

d. Horizontal or vertical (H or V).

e. Simplex or duplex (S or D).

f. Single-acting or double-acting (SA or DA).

503-4.5.2 A pump identified as 11 by 8 by 18 VSDA has an 11-inch steam cylinder, an 8-inch water cylinder, and an 18-inch stroke; and it is a vertical, simplex, double-acting pump.

503-4.5.3 To describe the rate at which a direct-acting steam pump operates, the terms cycle per minute (cpm) and revolution per minute (rpm) are often used interchangeably. A direct-acting pump contains no crankshaft and has no rotary motion, therefore the term, rpm, is not a completely accurate term. The correct term to describe the cycle rate of a direct-acting pump is cpm.

503-4.5.4 Most steam pumps are double-acting and because the conventional plunger is single-acting, two plungers and two individual pumping chambers are required for a simplex steam pump (four of each for a duplex).

503-4.6 STEAM PUMP OPERATING CHARACTERISTICS

503-4.6.1 The steam pump's capability to produce discharge pressure is dependent on the ratio of total steam force (steam pressure/unit area times area of steam piston) to total liquid force (pump head times area of liquid piston). For pumping to occur, the steam force must exceed the liquid force by an amount slightly in excess of the various mechanical and hydraulic losses. The basic principles for steam pump operation are illustrated in Figure 503-4-4. Formulas for calculating the pressure and capacity characteristics of particular steam pumps are included with the diagram.

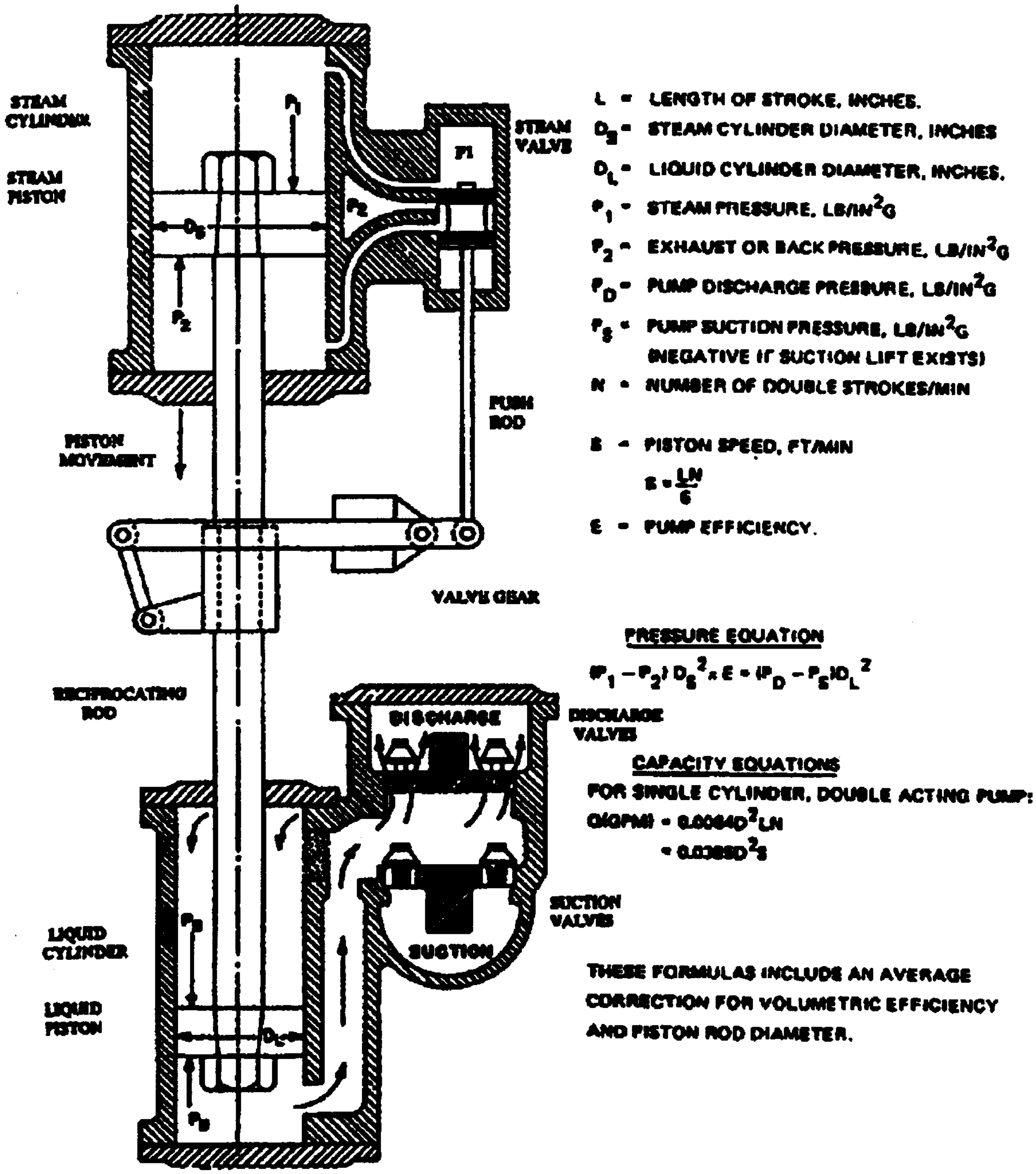


Figure 503-4-4. Basic Principles of Steam Pump Operation

503-4.6.2 Required steam conditions range from 150 to 600 pounds per square inch gage (lb/in^2 g) pressure and the corresponding saturated steam temperatures go up to 260° C (500°F).

503-4.7 STEAM PUMP APPLICATIONS

503-4.7.1 Direct-acting reciprocating pumps are used for the following applications:

a. Emergency feed.
b. Reserve feed transfer.
c. Fuel tank and bilge stripping.
d. Auxiliary feed.
e. Standby fuel service.
f. Fuel transfer.
g. Auxiliary circulating and condensate.
h. Fire and bilge.
i. Ballast.
j. High-pressure evaporator.
k. Lubricating oil transfer.
l. Cargo stripping.
m. General service.

503-4.8 STEAM VALVE AND VALVE GEARS

503-4.8.1 STEAM VALVE AND VALVE GEAR TERMINOLOGY. The following terminology applies to steam valves and valve gears:

a. Steam Valve - Steam valve is the portion of the steam end whose internal arrangement or porting allows high pressure steam or gas to enter one end of the steam cylinder while simultaneously exhausting the spent steam or gas from the opposite end.
b. Valve Gear - Valve gear is the actuating mechanism that moves the steam valve at the end of each pump stroke so that the steam piston reverses its direction of travel.
c. Auxiliary Valve - An auxiliary valve is provided with some simplex steam pumps to allow it to operate at low speeds without stalling. It is a steam valve which is actuated by the valve gear. The steam or gas is directed by the auxiliary valve to actuate the main steam valve.
d. Cushioning Valve - A cushioning valve is provided to dampen the pulsation of the steam flow caused by the reciprocating action of the steam piston.

503-4.8.2 TYPES OF STEAM VALVES. The steam valve serves as the pump actuating valve for direct-acting reciprocating pumps and is categorized by three types, all a function of the available steam pressure.

503-4.8.2.1 Direct-Acting Flat-Face D-Type Slide Valve. The direct-acting flat-face D-type slide valve is a flat, sliding valve having the general form of the letter D. The valve is suitable for low steam pressures of 150 to 200 pounds per square inch (lb/in^2) and below.

503-4.8.2.2 Steam-Thrown Piston Main Valve Actuated By A Flat-Faced Pilot Or Auxiliary Valve. The steam-thrown piston valve is a spool-shaped valve, which is actuated by a flat-faced pilot or auxiliary valve. This valve is suitable for moderate steam pressures up to 500 lb/in^2 and is often found on auxiliary ships converted from merchant ships.

503-4.8.2.3 Steam-Thrown Piston Main Valve Actuated By A Piston-Type Pilot Valve. The steam-thrown piston main valve is a spool-shaped valve, which is actuated by a piston-type pilot valve. The valve is suitable for use at high steam pressures and temperatures required for operation on naval ships. The piston main and pilot valves eliminate unbalanced loads and minimize steam leakage and wear.

503-4.8.3 OPERATION. Operating steam reciprocating pumps requires a working knowledge of the pump and its elements. This is especially true for the D-type slide valve. For detailed instructions, consult the appropriate technical manuals.

503-4.9 STEAM PUMP CAPACITY

503-4.9.1 Pumping capacity of a steam pump handling liquids is often provided by charts such as the one shown in Figure 503-4-5. The capacities indicated apply to vertical simplex pumps, in good repair, operating at full stroke. These data are found in the applicable technical manuals or manufacturers' catalogues. Capacity is equal to Pi multiplied by the square of cylinder diameter in inches, length of cylinder in inches and revolution per minute divided by 4 x 231 where 4 is from (pi)/4 for the area of a circle and 231 is the conversion of $inches^3$ to gallons.

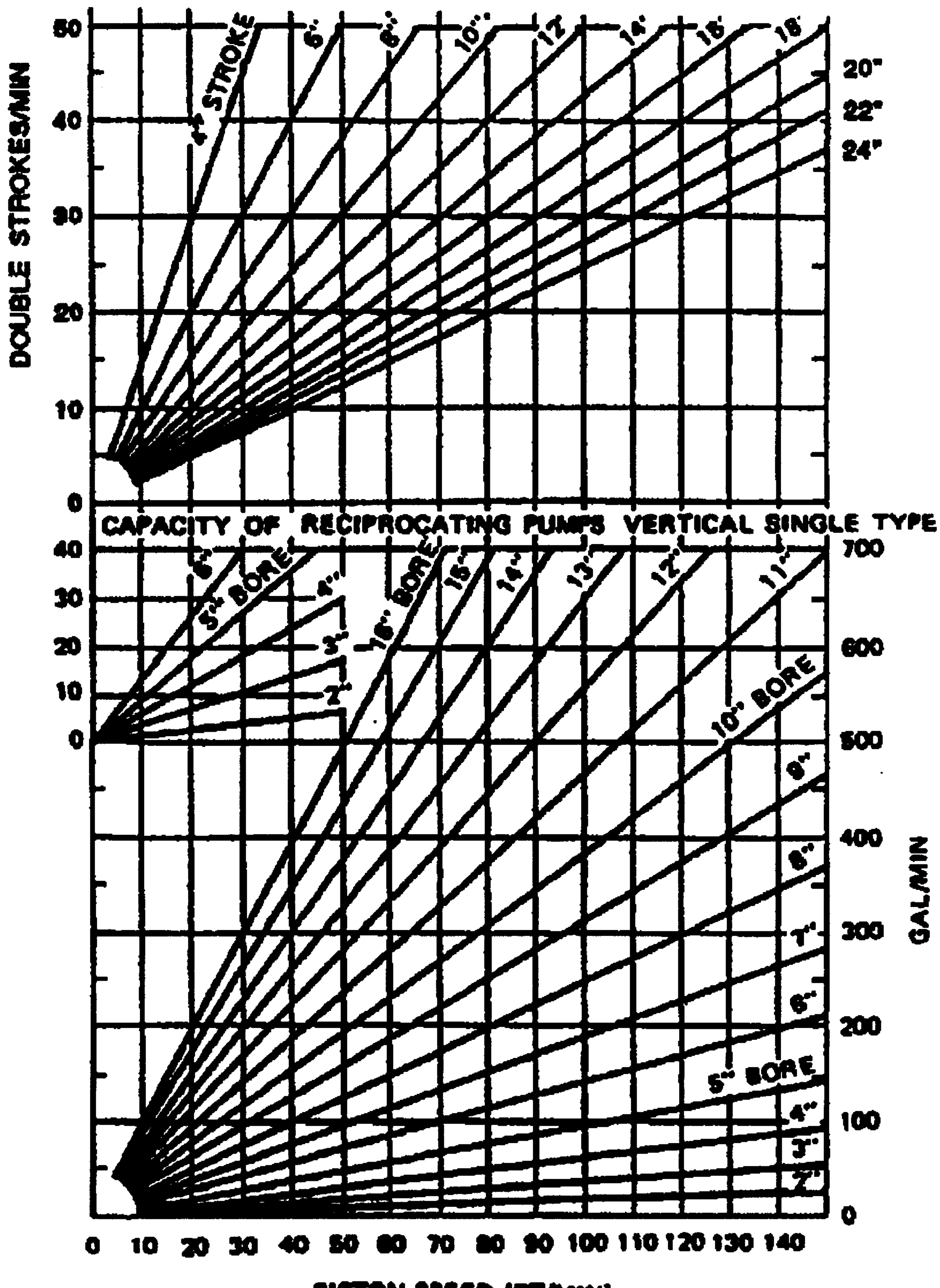


Figure 503-4-5. Reciprocating Pump Capacity Chart

503-4.10 POWER PUMPS

503-4.10.1 GENERAL. Low-pressure motor-driven reciprocating pumps, known as power pumps, are occasionally used in naval service for potable water, sanitary, bilge, ballast, and fuel transfer services. Small capacity power pumps are more efficient than other types and are self-priming. Such pumps are generally horizontal, and both plunger and piston types are used. An illustration of a typical horizontal, piston power pump is shown in Figure 503-4-6. Power pump crankshafts are driven from the motor by gearing or V-belt drives. The liquid ends of these pumps are similar to those of direct-acting steam pumps. General instructions for maintenance, repair, and safety are included in this section. Technical manuals or manufacturer instructions should be consulted for detailed information.

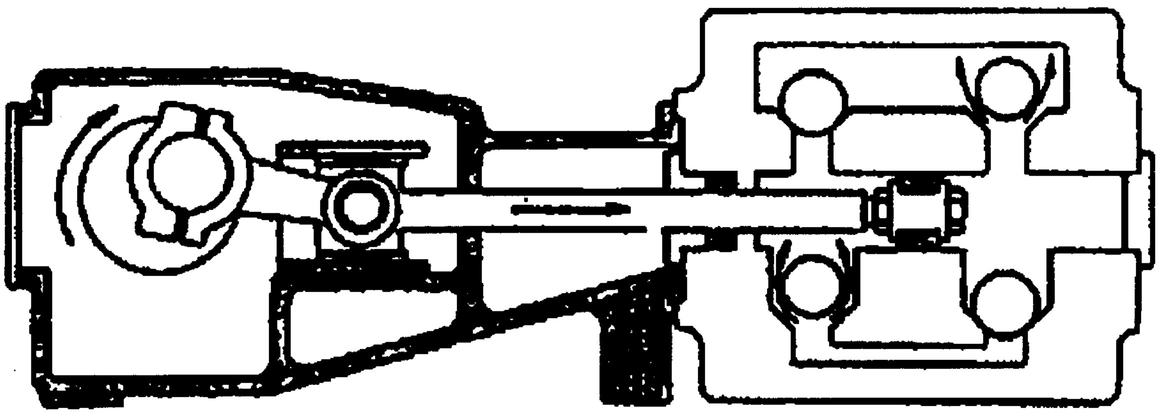


Figure 503-4-6. Horizontal Double-Acting Piston Power Pump

503-4.10.2 VARIABLE CAPACITY BOILER FEED PUMPS. Special types of plunger pumps were used for boiler feed service on auxiliary ships. These pumps are variable capacity triplex units and are governed by controlling the plunger stroke through use of automatic devices. This permits a stepless variation in capacity from zero to maximum, using a constant-speed motor or turbine. The inherent high efficiency of the plunger pump for low capacity at high pressure is thus maintained over a wide range of pump output. The general arrangement of the Worthington variable capacity boiler feed pump is shown in Figure 503-4-7, and the details of the crank, eccentrics, and stroke-shifting mechanism are illustrated in Figure 503-4-8.

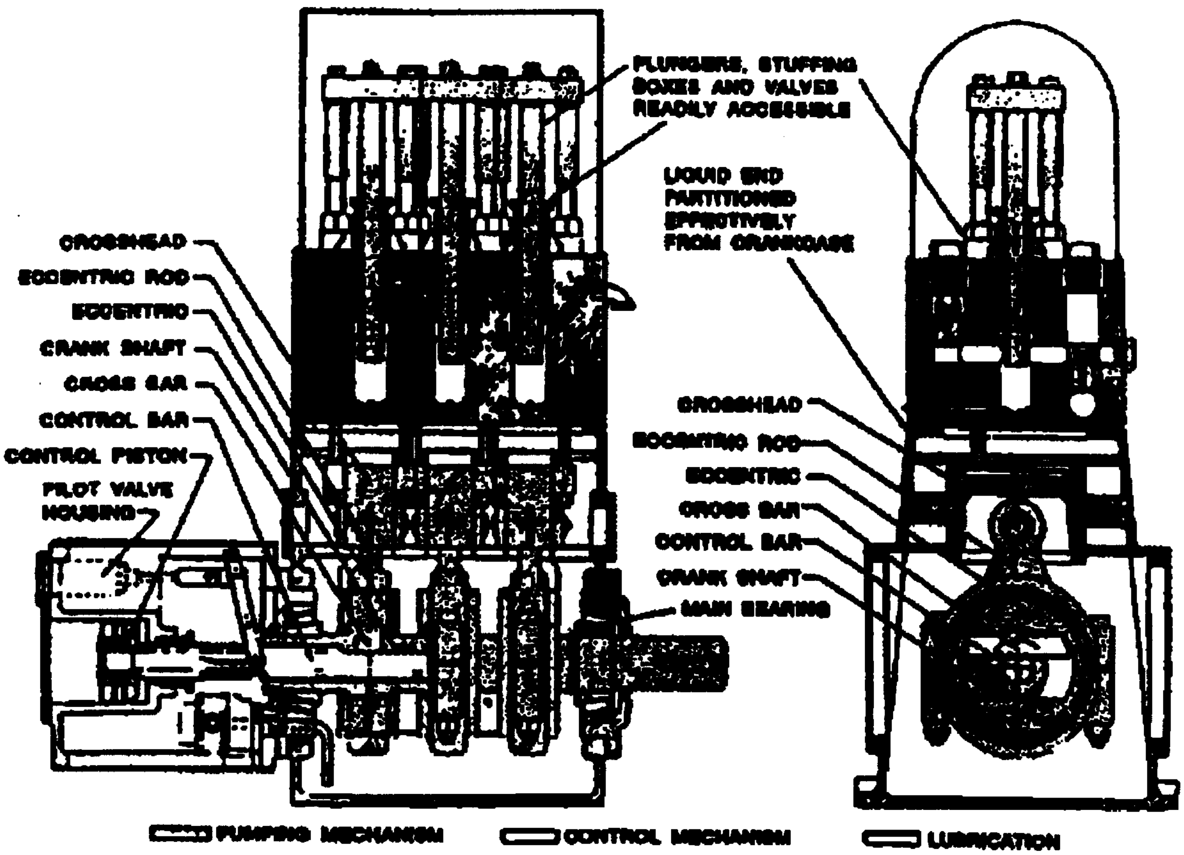


Figure 503-4-7. Worthington Variable Capacity Boiler Feed Pump

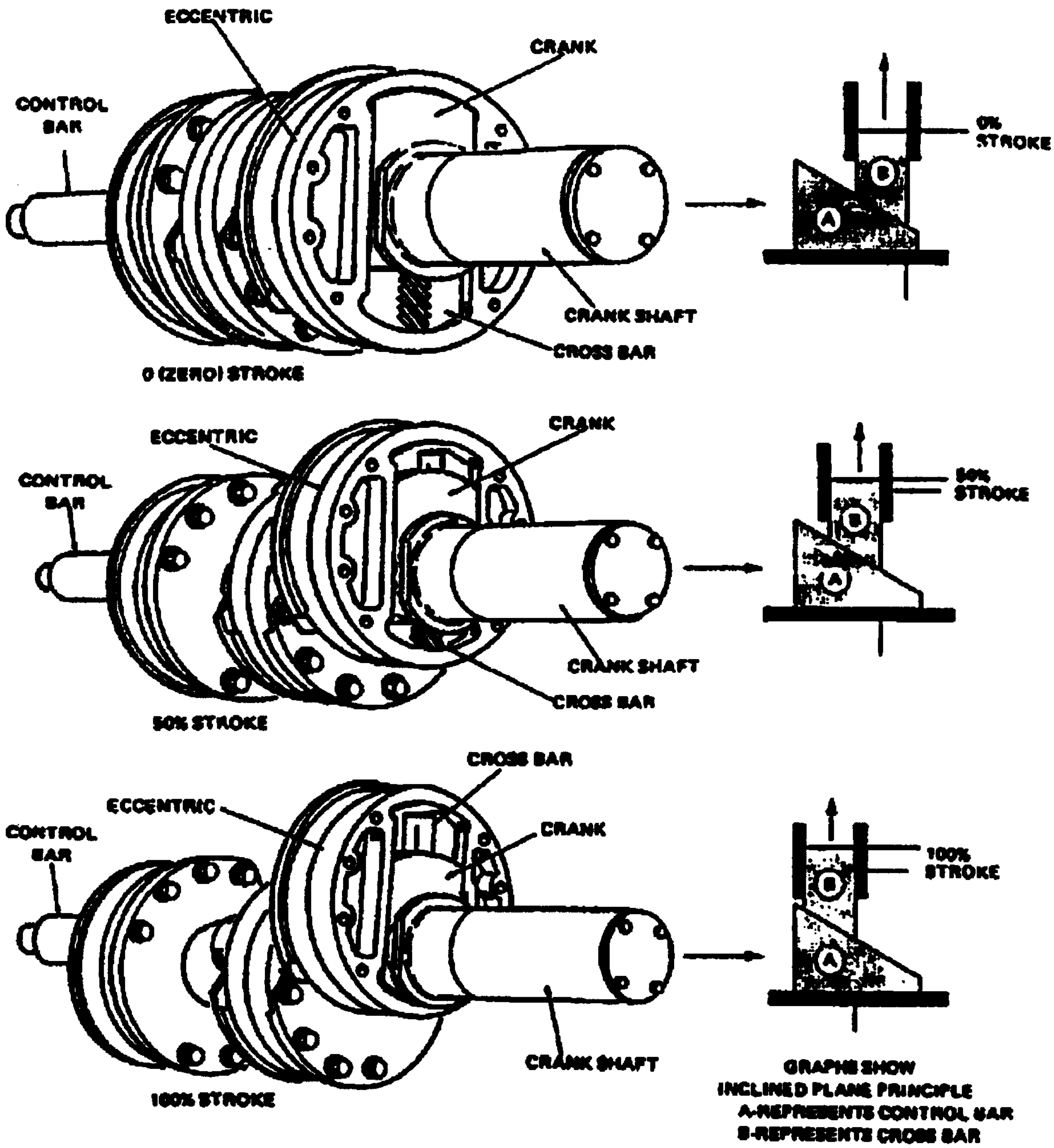


Figure 503-4-8. Crank, Eccentrics, and Stroke-Shifting Mechanism of Worthington Variable Capacity Boiler Feed Pump

503-4.10.3 CAM PUMPS. Another special type of plunger pump is the cam pump. The cam pump has a cam drive in lieu of a crankshaft and is used in high-pressure brine and sewage pump services on submarines. For a description of this pump, see the applicable technical manual.

503-4.11 CONTROLLED VOLUME PUMP (METERING, PROPORTIONING, OR CHEMICAL INJECTION PUMP)

503-4.11.1 CONTROLLED VOLUME PUMP TERMINOLOGY. The following terminology applies to controlled volume pumps:

a. Controlled volume plunger (or piston) pump - A pump used to accurately displace a predetermined volume of fluid in a specified time period. It contains a reciprocating plunger (or piston) in direct contact with the fluid being displaced and uses packing or seals to restrict leakage.

b. Controlled volume diaphragm pump - A pump used to accurately displace a predetermined volume of fluid in a specified time period. It contains a flexible diaphragm in direct contact with the process fluid being displaced. One or more diaphragms may be used and they may be flat or shaped. The diaphragm is driven mechanically or hydraulically.

c. Manual pump control - The pump mechanism for changing the displacement is manually adjustable.

d. Automatic pump control - The pump mechanism for changing the displacement is automatically adjusted by outside electrical, pneumatic, or hydraulic signals.

e. Mechanical diaphragm actuation - The push rod is mechanically coupled to the diaphragm which isolates the push rod from the process fluid.

f. Hydraulic diaphragm actuation - The plunger (or piston) is hydraulically coupled to the diaphragm(s) which isolates the plunger (or piston) from the process fluid.

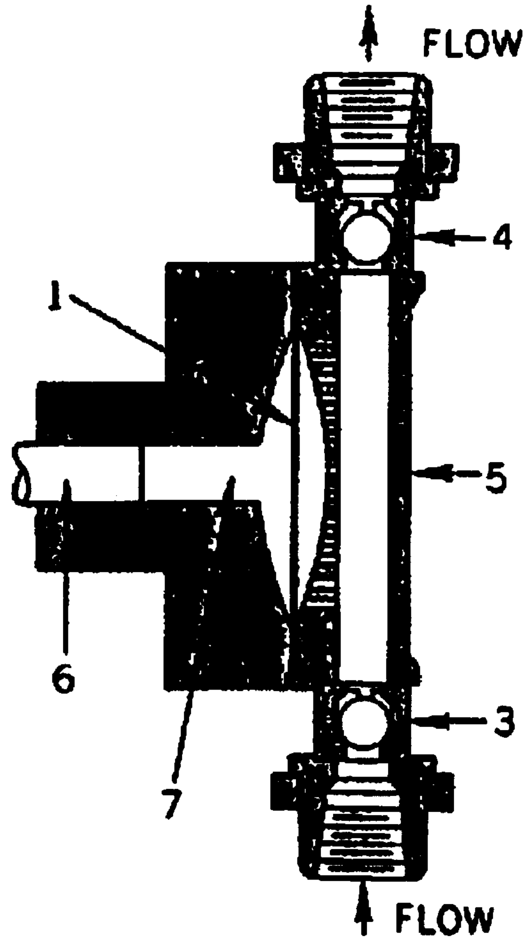
503-4.11.2 VARIABLE CAPACITY ADJUSTMENT OF CONTROLLED VOLUME PUMPS. Controlled volume pumps generally use one of the following types of mechanisms to vary the displacement of the pump and control the volume of fluid delivered. Depending upon the type of pump, these adjustments can be made either manually or automatically.

a. Adjustable throw of the crankshaft driving the displacement plunger, piston, or push rod.

b. Adjustable mechanical stops limiting the stroke of the displacement plunger, piston, or push rod.

c. Absorption of a portion of the plunger or piston stroke to regulate diaphragm displacement by internal hydraulic bypass.

503-4.11.3 VARIABLE CAPACITY DIAPHRAGM PUMPS. Variable capacity diaphragm pumps are used for chemical injection on distilling plants on a number of ships. The hydraulic fluid between the plunger and diaphragm transmits the reciprocating motion of the plunger to the metered fluid. The diaphragm separates the metered fluid from the plunger and hydraulic fluid. The diaphragm is constructed either of metal or elastomer materials and is designed to withstand maximum flexing without rupture. A typical arrangement of a liquid end diaphragm assembly is shown in Figure 503-4-9.



1 Diaphragm, Flat
3 Suction Valve Assembly
4 Discharge Valve Assembly
5 Liquid End Head
6 Plunger
7 Hydraulic Oil

Figure 503-4-9. Liquid End Assembly, Hydraulically Actuated Diaphragm Pump

503-4.12 RECIPROCATING PUMP OPERATION

503-4.12.1 PREOPERATION. Refer to the Engineering Operation Sequence System (EOSS) or the equipment technical manual for reciprocating pump preoperation checks, starting, stopping, and securing procedures. The following general warning and caution should be observed.

WARNING

Ensure that system relief valves and steam relief valves are operational. Failure of these valves to relieve pressure may cause damage to equipment and injury to personnel.

CAUTION

Ensure that steam is admitted slowly when starting steam pumps so that the equipment warms up gradually. Failure to do this may cause damage to equipment.

503-4.12.2 FAILURE TO START POWER OR CONTROLLED VOLUME PUMPS. If a power or controlled volume pump fails to start:

1. Secure the pump; do not attempt to make any adjustments to any of the pump control mechanisms or devices.
2. Examine the pump suction and discharge lines for closed cutoff valves. If any are closed, open them.
3. If belt driven, check the belt tension. If electric motor driven, check the shaft coupling. Repair as required.
4. If motor driven, verify that the motor is receiving the proper voltage and current.

503-4.12.3 FAILURE TO START STEAM PUMPS. If a steam pump fails to start:

1. Secure the pump; do not attempt to adjust the tappet collars.
2. Examine the discharge and exhaust lines for closed valves or for a valve disk that has become detached from its stem. If no valve is found closed, the steam piston may be frozen, particularly if the pump has not been in service for some time. With the steam turned off or isolated and the drains open, move the pump rod with a bar to determine if there is excessive friction; if so, correct it.
3. Disconnect the auxiliary valve stem from the operating gear without disturbing the tappet collar adjustment. Open the exhaust, suction, and discharge valves and then crack the throttle. By hand, work the auxiliary valve. (It should work freely.)
4. Should the pump still fail to start, open the drains and secure it in accordance with EOSS or the equipment technical manual. Remove the steam valve chest cover and examine the main valve to see if it has overridden or is stuck.
5. If the pump still fails to start, a complete overhaul of the steam end is necessary to stop steam leakage (in either steam piston or valves) which is the most probable cause of the failure to start.

503-4.12.4 TROUBLESHOOTING. Troubleshooting reciprocating pumps will require a working knowledge of the pump and its system. This is especially true of the controlled volume pumps. For detailed instructions, consult the appropriate technical manuals. The following paragraphs provide a general troubleshooting guide for reciprocating steam pumps. Some of the information may be applicable to power pumps and controlled volume pumps.

WARNING

If a steam pump should stop or seize, do not use a jacking bar with steam turned on; to do so may result in serious damage to the pump or injury to personnel.

503-4.12.4.1 Discontinuous Or Jerky Operation. Discontinuous or jerky operation on starting is usually caused by failure to take suction or tight piston packing. To diagnose and remedy this problem, ensure that all stop valves or check valves in the suction line are open and that the line is clear of obstructions.

503-4.12.4.1.1 If a steam-powered feed pump becomes vapor-bound when taking suction from a variable speed booster pump, immediately speed up the booster pump. Unless the feed pump regains suction immediately, shift suction to the reserve feed tank until the vapor-bound feed pump cools off. If a standby feed pump is available, shift to it until the vapor-bound pump has cooled. In some cases, low pressure air could be used to cool the vapor-bound pump cylinder. If drain valves are provided on pump valve chest covers or discharge line, open them to assist the pump in releasing the vapor.

503-4.12.4.1.2 Pumps having suction lift, such as bilge pumps, may require priming before they will take suction. Seawater pumps can usually be primed from the sea by opening the sea suction valve for a short time.

503-4.12.4.2 Discharge Pressure Loss. When the pump loses discharge pressure, investigate and determine whether steam pressure is low, back pressure is high, piston rings in the steam end are worn, or there is excessive friction because of overtightened packing stuffing boxes or liquid piston packing binding.

503-4.12.4.2.1 A racing pump may also exhibit a loss in discharge pressure. Stop the pump as soon as practical to diagnose and correct the problem. Such racing is caused by a leaky piston; a leaky, broken, or stuck valve in the liquid end; or by air being admitted through open or leaky valves in the suction line.

503-4.12.4.2.2 If a pump which has been running properly suddenly loses pressure on one stroke, one of its valves may be defective. Secure the pump and look for a broken valve. Broken valves should be replaced at once. Leaky suction and discharge valves and leaky pistons will also reduce the efficiency of the pump. Under ordinary conditions the first investigation should, of course, be made of the most accessible parts.

503-4.12.4.3 Capacity Loss. Loss of capacity and failure to develop pressure are closely related problems; loss of pump capacity will generally be reflected in failure to develop pressure. Some additional causes of a capacity loss are:

a. Insufficient pump speed.

b. Excessive suction lift.

c. Air leaks into the pump through an opening between the rod and packing, or leaks in the suction line.

d. Entrained vapors in pumped liquid.

503-4.12.4.4 Pounding. Pounding in the liquid end can be caused by improper steam cushioning, liquid valves that are stuck, or a loose piston. To eliminate the pounding, adjust the steam cushioning valves on a duplex pump. Examine the pistons to see that they are tight on the rod. Tighten if necessary. Check the valve rod for lost motion on a simplex pump. Adjust if necessary. Look for loose valve nests and zinc plates or pencils, if fitted, and tighten as necessary.

503-4.12.4.4.1 If the pounding pump is not fitted with an air chamber on the suction side, a snifting valve installed on the suction side usually stops the pounding.

NOTE

An air chamber should be fitted in suction lines if the liquid velocities are high. Make sure the air chamber is properly charged.

503-4.12.4.4.2 To stop pounding in the water end of a pump which has a considerable suction lift, reduce the pump speed. In this case, the pounding usually is caused by water hammer or a ram effect in the suction piping.

503-4.12.4.5 Groaning. Groaning in the pump water end is generally caused by the packing being too tight, but groaning may be the result of misalignment, a broken follower, or a stuck valve. The pump should be stopped and examined at once; failure to investigate may result in burned packing or a scored cylinder.

503-4.12.4.6 Erratic Operation. When a pump operates erratically, sticks in any part of the stroke, or stops frequently even though the throttle valve is properly opened, the problem may be caused by:

a. Lost motion in the operating gear caused by worn parts.

b. Steam leakage from the main or the auxiliary valve caused by water in either valve. To remedy this, check the defective main or auxiliary valve for contact on its seat. To check the defective main or auxiliary valve, blue the metal-to-metal joint and check for a complete line of contact around the seat. If the fit is not good, lap the surfaces until complete contact is achieved. Otherwise, replace the defective valve. If the valve chest piston continues to leak steam or sticks, it may be necessary to rebore the valve chest cylinder or renew or refit the piston rings.

503-4.12.4.6.1 Excessive leakage from the steam piston rings can be remedied by reboring and honing the steam cylinder or renewing the rings, or both. When cylinders are rebored, oversized pistons should be fitted.

503-4.12.4.6.2 Erratic operation can occur if small ports and passages in the valve chest are blocked by scale. This frequently happens on new ships if steam lines are not blown free of all scale before they are connected.

503-4.12.4.7 Steam End Knocking. Knocking in a steam cylinder is indicative of a loose piston or piston assembly. The pump should be stopped immediately and the exact cause discovered and corrected.

503-4.12.4.8 Steam End Groaning. Steam cylinder groaning is usually caused when the steam piston is cocked on the piston rod, rings are broken, or cylinders are out of alignment. The trouble, unless immediately corrected, will result in scored cylinder walls. If a pump has been idle for a long period, rust sometimes forms on the piston or cylinder and may cause groaning when the pump is started.

503-4.12.4.9 Worn Piston Rings. If the pump stops when going very slowly, worn piston rings, worn cylinder, or improper ring position are indicated. The appearance of a good bearing on the piston ring does not necessarily indicate a good fit. Steam may be leaking through the piston rings. The rings need to be removed from the cylinder so measurements of both rings and cylinder may be checked for excessive clearance.

503-4.12.4.10 Hydraulic Action. If a pump is fully primed with the discharge outlet tightly closed and steam admitted to the steam cylinder, the pump piston and rod should not move unless there is slip or leakage from one side of the pump piston to the other. Under these conditions, on the down stroke, (the stroke where the pump rod enters the liquid cylinder) the liquid pressure in the cylinder will build up in proportion to the ratio of the area of the steam cylinder to the area of the pump rod.

503-4.12.4.10.1 For example, assume that a steam cylinder is 11 inches in diameter, with the pump rod 2-5/8 inches in diameter, and the steam pressure is 575 lb/in^2 . The resulting liquid pressure is:

$$\frac{\frac{\pi(11)^2 x575}{4}}{\frac{\pi(2.625)^2}{4}} = \frac{95.03\ x575}{5.42} = 10,081\ \mathrm{lb/in^2}$$

503-4.12.4.10.2 If hydraulic action is allowed to occur, the liquid cylinder may break. This can happen when the pump is secured and the steam throttle valve leaks or is not carefully closed.

503-4.12.4.10.3 To prevent hydraulic action, always open steam cylinder drain valves when the pump is shut down and leave them open until the pump is again started and cleared of condensation. Ensure that the relief valve in the discharge line functions properly and that it is located between the pump and discharge shutoff valve in the discharge line.

503-4.12.4.11 Vapor Lock. Fuel oil transfer pump suction lines, in particular, may have vapor pockets because of high points in the line and may be accompanied by considerable gasification. With a vacuum on the suction line, this gasification will cause vapor locks wherever pockets exist. Vapor lock may also occur when a new oil supply has been provided.

503-4.13 MAINTENANCE

503-4.13.1 GENERAL. Maintenance of reciprocating pumps will require a working knowledge of the pump and its system. For detailed instructions, consult the appropriate technical manuals. The following paragraphs provide a general maintenance guide for reciprocating steam pumps. Some of the information may be applicable to power pumps and controlled volume pumps.

NOTE

Maintenance information provided in this chapter is intended to supplement preventive and corrective maintenance procedures under the 3-M Planned Maintenance System (PMS). Maintenance procedures shall be as specified on Maintenance Requirement Cards (MRCs). If inconsistencies are noted, OPNAV 4700/7, PMS Technical Feedback Report (TFBR), should be submitted.

503-4.13.2 LUBRICATION. The valve operating gear pins should be oiled frequently. Never use oil in the steam or water cylinders, the valve chest, or on piston rods.

503-4.13.3 JACKING REQUIREMENTS. All steam pumps should be inspected and cycled (jacked) prior to startup, in accordance with specified PMS and Engineering Operational Sequencing System (EOSS) procedures. Steam pumps that require periodic startup when not in routine service shall be operated in accordance with specified PMS and EOSS procedures at the defined periodicity.

503-4.13.4 GLAND LEAKAGE. Great care should be exercised when tightening gland nuts. If the two sides are tightened unequally, the gland becomes tilted and may score the rod, and may also break the gland. If a gland is overtightened the packing may score the rod. If a gland continues to leak excessively after the nuts are turned a few times, do nothing further until the pump can be shut down. An examination should then be made to determine if the throat bushing bore is too large, possibly due to the rod having been turned down, or to see if new packing is needed, or the incorrect packing size is installed.

503-4.13.5 STEAM VALVE CHESTS. Preventive maintenance of steam valve chests operating under high steam pressures is important to avoid serious steam cutting and wear. Routine inspections will disclose early signs of leakage or wear and need for corrective action. Careful attention to lapping out these early cuts will ensure a tight metal-to-metal valve chest and steam cylinder fit. Inspection of the piston rings on the main and auxiliary valves, along with timely replacement, may prevent broken rings and steam cutting in the grooves.

503-4.13.5.1 The valve chest and steam cylinder metal-to-metal joint should be blued and inspected for good overall contact before it is secured. If the metal-to-metal fit is not good (scores or leakage are evident), remove the studs from the steam cylinder and lap the steam chest in against the cylinder seat. Reblue and inspect for overall contact.

503-4.13.5.2 Strict cleanliness must be observed in securing the joint. Dirt or scale particles will prevent a good metal-to-metal contact of the ground faces. A thin film of non-hardening joint sealing compound designed for steam service should be applied. The hold-down bolts should be taken up gradually and alternately in a diagonal sequence. After steam is applied and the pump is in operation, the hold-down bolts should be retightened in the same sequence.

503-4.13.5.3 Do not install gaskets on the steam chest joint. Gaskets tend to blow out around the steam passage lands and create a steam cutting action.

503-4.13.5.4 When repeated lappings have worn the valve chest and steam cylinder surfaces to a point beyond their tolerance limit, consult the pump technical manual for remedial action that can be accomplished by ship's force.

503-4.13.6 STROKE ADJUSTMENT. To operate properly, pumps should be run at full stroke, thus ensuring that the piston will travel slightly beyond the counterbore. Full stroke travel information is stamped on the nameplate. A stroke indicator, consisting of a pointer to the piston rod crosshead and two marks on one cylinder tie rod, is usually provided. The upper mark lines up with the pointer on the crosshead when the pump is at the upper end of its stroke, while the lower mark indicates the pointer's proper position with the pump at the lower end of its stroke. If such a stroke indicator is not already fitted, it should be installed to ensure steam economy and efficient pump operation.

503-4.13.6.1 When full stroke cannot be obtained, check the pump stroke adjustments. A short stroke results in incomplete cushioning and formation of shoulders in the cylinders and valve chests. This may result in breakage of rings and followers. A long stroke is usually indicated by a heavy metallic steam cylinder knock and should be corrected immediately.

503-4.13.6.2 It should not be necessary to move the tappet collars repeatedly while the pump is running. If it is necessary to do so, the pump is malfunctioning and should be dismantled and the interior parts examined. Do not alter the settings of the tappet collars without orders from the Engineering Officer.

503-4.13.6.3 The steam valve setting must be carefully adjusted to make a pump take a full stroke. Refer to the manufacturers' drawings and instruction books for detailed information on the method to be followed for specific makes and types of valve gear. A general method is included in the following paragraphs when more detailed information is not available.

a. Simplex pump steam valve setting. On simplex pumps, adjusting the lost motion mechanism changes the length of the stroke. A simplified method of adjustment is as follows:
   1. Place pistons and auxiliary valve at mid-stroke. Then move each tappet collar about 1/2 the width of the steam port away from the tappet.
   2. Start the pump. If the stroke is too short, the collars should be screwed farther apart. Care should be taken to move both collars the same amount; otherwise, the stroke will be longer on one end.
   3. After the final adjustment has been made, lock the collars securely in place.

b. Duplex pump steam valve setting. A simplified method of adjustment is as follows:
   1. Place one piston on its top striking point and, by removing the steam chest cover of the other piston's valve chest, adjust and secure the other piston's steam valve to give an excess of 1/8 inch of full port opening at the top end. To set the other steam valve, repeat the operation with the other piston.
   2. Run the pump slowly with the throttle cracked against little or no pressure and with the cushioning valves (if fitted) wide open. The pistons should be striking on the cylinder heads; if they do not, some undue friction exists, possibly caused by tight piston rod and plunger packing. Close down on the cushioning valves until the pump is running at full stroke of both steam pistons with reversal and no striking. If it is impossible to obtain smooth reversal, it may be necessary to alter the adjustment of the valve operating collars.

3. To shorten the length and prevent the piston from striking against the cylinder heads, set the adjustment closer together; to lengthen the stroke, set the adjustment farther apart.

503-4.13.6.4 Because of design characteristics or wear, some pumps may override and pound at full speed after having been adjusted to give full stroke at low speed. The only remedy for this is to have different valve adjustments for different speeds.

503-4.13.6.5 After a pump has run on short stroke for a considerable time, difficulty may be encountered in making the pump take a full stroke because the shoulders will have been formed in the steam valve seat and pump cylinder lining. These shoulders will have to be removed before full stroke can be obtained.

503-4.13.7 CORROSION PROTECTION. On seawater pumps having cast iron bodies and parts in contact with seawater, special care shall be taken to guard against corrosion. Every 6 months, these parts shall be examined, scaled, and wire-brushed as practical. Corrosion can be reduced by fitting zinc plates or rings on water end valve chest and cylinder covers.

503-4.13.8 WATER VALVE EXAMINATION. For satisfactory and economical pump operation, the liquid end valves must be absolutely tight. The liquid end valves in all pumps should be examined in accordance with PMS periodicity requirements and all foreign matter on valves, valve stems, and valve springs removed.

503-4.13.9 TEST AND INSPECTIONS. Reciprocating pumps should be tested or inspected periodically in accordance with PMS requirements.

503-4.14 REPAIRS

CAUTION

Only qualified personnel should attempt repair of these pumps.

503-4.14.1 DRAWINGS AND DATA. When a pump is to be repaired or examined, assembly and detail drawings along with available dimensional data must be at hand. After overhaul, important dimensions frequently become altered (for example, the width of and distance between steam ports, the length of rods and steam valves, and the diameter of pistons). These changed dimensions may cause poor operation that will continue, despite other major repairs, until the real cause of the problems is recognized and corrected.

503-4.14.2 MEASUREMENTS. Whenever reciprocating pumps are opened for repairs, measurements of the cylinders and valve chest on the fore, aft, and athwartship diameters at the top, middle, and bottom shall be taken with a micrometer. The results of these measurements shall be recorded on OPNAV Form 4790-2K and OPNAV Supplement Form 4790-2L, with an accompanying diagrammatic sketch showing measurements obtained and relevant data.

503-4.14.3 SPECIFIC REPAIRS. Specific problems and remedial action that can be taken by ship’s force are described in pump technical manuals.

SECTION 5.

MECHANICAL SEALS AND PACKED STUFFING BOXES

503-5.1 GENERAL DESCRIPTION

503-5.1.1 A seal is required in the pump stuffing box to prevent excessive leakage at the point where the shaft passes through the pump casing. If the pump is installed in a suction lift condition and the pressure at the inner end of the stuffing box is less than atmospheric pressure, the seal prevents air from leaking into the pump. If the pump is working under positive suction head, the seal prevents liquid from leaking out of the pump. Two types of seals are used in a pump stuffing box: mechanical seals or packing. The primary sealing face of a mechanical seal is perpendicular to the shaft, whereas packing seals along the shaft or shaft sleeve. Mechanical seals are used in pumps with rotating shafts only (centrifugal and rotary), whereas packing may be used in pumps with shafts that rotate or move axially (reciprocating).

503-5.2 TERMINOLOGY

503-5.2.1 The following terminology applies to mechanical seals and packed stuffing boxes:

a. Stuffing box (seal chamber) - A portion of the casing through which the shaft extends and in which packing and a gland or a mechanical seal is placed to prevent leakage.

b. Backup stuffing box - A recessed portion of the gland and cover of a mechanical seal subassembly designed to accommodate two or more rings of packing.

c. Mechanical seal - A mechanical device located in the pump stuffing box consisting of a stationary element and a rotating element, each with a smooth, flat sealing face that prevents the flow of a liquid or gas into or out of the pump casing.

d. Packing - A pliable lubricated material used to provide a seal around that portion of the shaft located in the stuffing box.

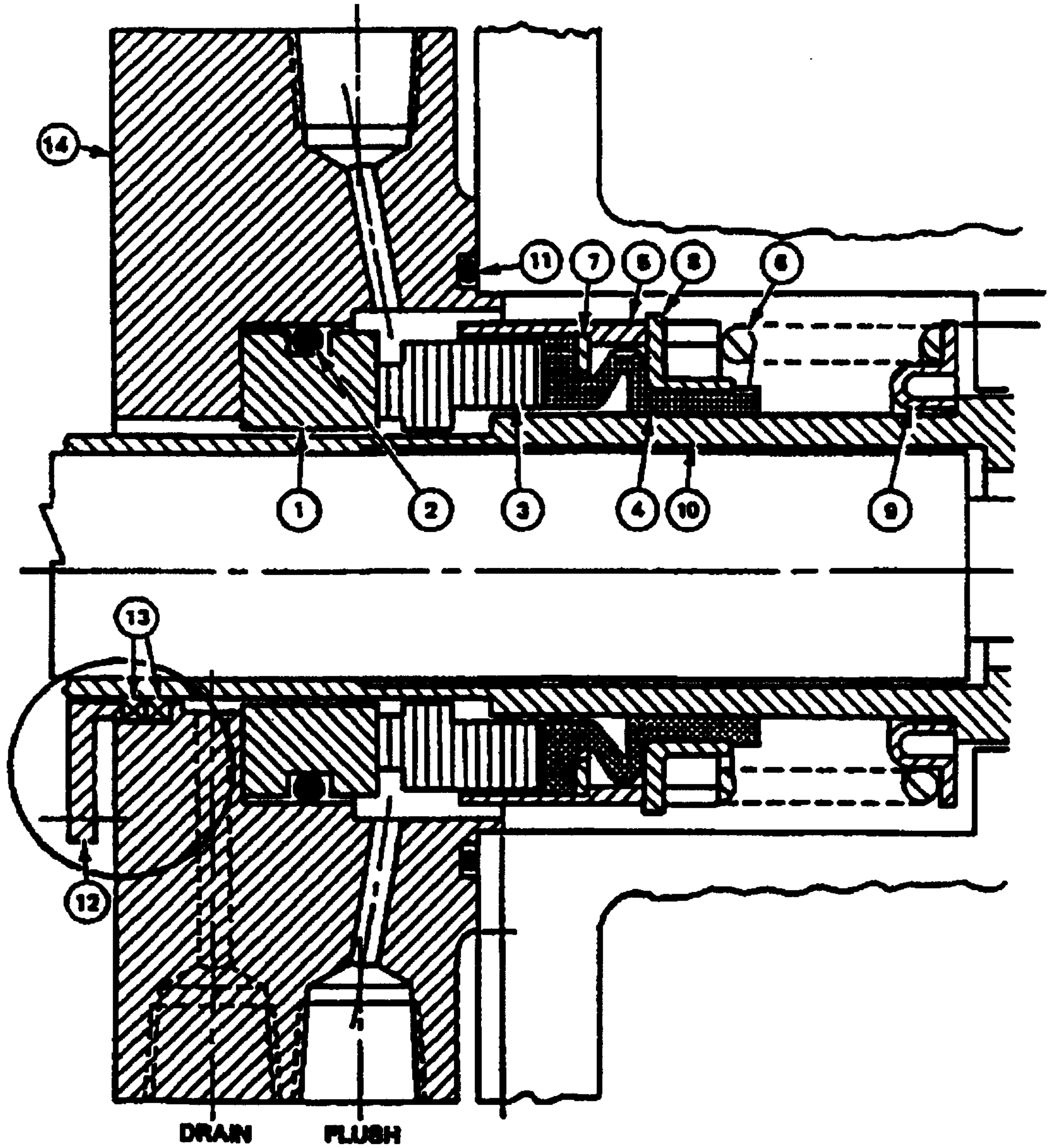
e. Gland - A follower which compresses packing in a stuffing box or retains the stationary element of a mechanical seal.

f. Lantern ring - An annular piece used to establish a liquid seal around the shaft and to lubricate the stuffing box packing. Lantern rings are used in a suction lift condition to prevent air leakage into the stuffing box.

g. Shaft sleeve - A cylindrical piece fitted over the shaft to protect the shaft through the stuffing box and which may also serve to locate the impeller on the shaft.

503-5.3 MECHANICAL SEALS

503-5.3.1 BASIC CONSTRUCTION. A mechanical seal consists of a stationary element fixed within the pump casing, cover, or gland and a rotating element connected to the pump shaft or shaft sleeve. Each element includes a seal ring whose face has been highly lapped. The materials of the rotating and stationary seal faces are selected for a combination of low friction and resistant to corrosion by the liquid being sealed. The mechanical seal is designed to operate with the seal faces in close contact with a very thin film of the liquid being sealed between them to reduce friction and wear. One of the elements, either the rotating or the stationary element, of the mechanical seal is provided with axial flexibility, usually in the form of a spring assembly and sliding elastomer seal. This allows the mechanical seal to function properly, maintaining the very thin film of fluid between the seal faces, while accommodating the normal axial movement between the pump shaft and the pump casing. The spring assembly is preloaded to ensure that the mechanical seal remains closed while the pump is depressurized. Figure 503-5-1 illustrates a typical mechanical seal.



NO.	PART	NO.	PART	NO.	PART
1	MATING RING	7	DISC	13	PACKING
2	O-RING	8	DRIVE BAND	14	GLAND
3	PRIMARY RING	9	SPRING HOLDER		
4	BELLOWS	10	SLEEVE		
5	RETAINER	11	O-RING		
6	SPRING	12	AUX. GLAND		

Figure 503-5-1. Typical Non-pusher Mechanical Seal

503-5.3.2 SEAL OPERATION. Successful operation of a mechanical seal depends on proper installation, an adequate supply of clean flushing liquid, and proper venting of the stuffing box. Mechanical seals should never be operated dry, without sealing liquid in the pump stuffing box. The seal depends on the cooling provided by the liquid in the stuffing box and the lubrication provided by the thin film of liquid between the seal faces for proper operation. Unlike packing, mechanical seals do not require periodic adjustment during operation and should operate with negligible leakage without attention.

503-5.3.3 MECHANICAL SEALS PREFERRED. Mechanical seals (Figure 503-5-1) are preferred over packing in most cases because they minimize stuffing box leakage. They are not used for centrifugal pumps which may run dry or cannot provide an adequate supply of flushing liquid. Mechanical seals for Navy applications are being standardized through the development of a Navy appendix to ASTM specification F-25.11.11. When replacing a mechanical seal, only the mechanical seal identified on the pump APL should be used. Ceramic sealing faces are not acceptable in pump mechanical seals. All replacement of ceramic seal face materials should also be done in accordance with the pump APL. If the APL has not been updated to include approved materials, contact NAVSEA. Typically, a backup stuffing box which accommodates two or more rings of packing for use in the event of a seal failure is provided on surface ships.

503-5.3.4 SEAWATER PUMPS. Seawater pumps for submarines are provided with mechanical seals and pressure breakdown devices. The pressure breakdown device limits the leakage to an acceptable level if the mechanical seal fails under the maximum suction pressure for which the pump is designed. Seawater pumps have a backup stuffing box designed with a minimum of four packing rings for use if the mechanical seal fails. The packing rings may be inserted without removing the mechanical seal.

503-5.3.5 FIRE PUMPS. Fire pumps and all other centrifugal seawater pumps with a total head of 30 psi or more are usually provided with cyclone separators. Cyclone separator fittings and the pump casing are the straight-thread type with an O-ring seal. Cyclone separator tubing and fitting material for seawater pumps except fire pumps is copper-nickel (70-30) in accordance with MIL-T-16420. Cyclone separator, tubing, and fitting material for fire pumps is titanium.

503-5.3.6 MECHANICAL SEAL MATERIALS. The approved mechanical seal materials are the following:

a. Rotating Sealing Face (primary ring) - carbon-graphite (as approved by NAVSEA), silicon carbide, or nickel-bound tungsten carbide (solid construction only)

b. Stationary Sealing Face (mating ring) - nickel-bound tungsten carbide (solid construction only) or silicon carbide

c. Elastomers - fluorocarbon

503-5.3.7 AXIAL POSITIONING. Mechanical seals are axially positioned on the pump shaft by positive means, such as a step or shoulder on the shaft, or by a stub or step sleeve that is positively located on the pump shaft. Seals are not axially positioned by set screws or by sleeves held in place by set screws: set screws do not provide a secure connection to the shaft, and upset metal on the pump shaft can damage O-rings installed over the pump shaft.

503-5.3.7.1 The axial positioning of the shaft seal during installation is a critical factor in achieving reliable seal operation. With the seal installed in the correct position, the spring assembly provides the proper axial preload to the seal faces and sufficient axial travel so that the normal end-play, seal-face wear, and thermal growth of the pump shaft can be accommodated without affecting the thin film of liquid between the seal faces. Incorrect axial positioning of a mechanical seal can force the seal faces to separate, causing excessive leakage, or force the seal faces into hard contact, causing seal-face deterioration.

503-5.3.7.2 The procedure for setting the axial position of a mechanical seal is specific to the application, and the procedure given in the Technical Manual should be used. In most cases the axial position is set by a step or shoulder on the shaft sleeve; however, in some special applications, such as submarine seawater pumps, the seal axial location may be set using shims to accommodate variations in the pump dimensions.

503-5.3.7.3 When replacing seals or other pump parts affecting axial seal location, such as shaft sleeves, do not reuse shims without verifying that they produce the proper seal location.

503-5.3.8 LEAKAGE AND REPLACEMENT CRITERIA. Leakage and replacement criteria for mechanical seals follow.

503-5.3.8.1 Non-Flammable Liquids. When non-flammable liquids are being pumped, mechanical seals shall be replaced:

a. Whenever the seal is removed for any reason.

b. Whenever the leakage drop rate approaches a steady stream.

c. Whenever pump performance is degraded.

d. Whenever the leakage causes undesirable effects on equipment or surrounding spaces.

WARNING

See paragraph 503-5.3.8.2 for guidance for centrifugal pumps pumping fuel oil, JP-5, gasoline, or other flammable liquid.

503-5.3.8.1.1 The following applies to non-flammable, combustible liquid pump services, such as lube oil:

a. Leakage Test:
   1. Observe and collect leakage for a 1-minute period.

b. Replacement Criterion:
   1. Permissible leakage for new seals is 5 to 7 drops per minute. Seals need not be replaced until the leakage rate is excessive, causing a safety hazard or a maintenance burden.

NOTE

If emergency backup packing is installed, the leakage and replacement criteria in paragraph 503-5.4.3 for packed stuffing boxes apply.

503-5.3.8.2 Flammable Liquids. The following applies to flammable liquid pump services (that is, fuel oil, JP-5, gasoline, and so forth):

a. Leakage Test:
   1. Wipe pump tell-tale hole or seal housing dry of any dampness.
   2. Observe and collect leakage for a 30-minute period.

b. Replacement Criterion:
   1. Zero measurable (dripping) leakage is permitted over the 30-minute period for satisfactory seal performance (slight dampness at the tell-tale hole or seal housing is acceptable).

503-5.3.8.3 Mechanical Seal Self-Healing. Seals which leak in excess of the preceding criteria should be changed out at the first opportunity that is not disruptive to ship's operations. Seal leakage which causes an immediate safety hazard shall be corrected without delay. However, seals have the ability to self-heal in many cases and if applicable, it is recommended that the following procedure be observed prior to change out: Leakage which is unacceptable per the preceding criteria should be monitored for a 2-hour operating period. If the leakage rate decreases to a level which is considered acceptable per the preceding criteria, the seal should remain in service. If the leakage does not decrease to an acceptable level, the seal should be replaced.

503-5.3.9 INSTALLATION OF MECHANICAL SEALS. Procedures for installation of mechanical seals are specific to the seal manufacturer, pump design, and the application. The application- specific installation procedures should be used. The instructions provided here provide general guidance.

503-5.3.9.1 Cleanliness. The reliability of a mechanical seal depends on it being free of debris that could interfere with the proper movement of internal parts or the proper mating of tightly-toleranced parts.

a. Remove any loose matter from the pump shaft, stuffing box, gland plate, and other stationary parts. Wipe these parts clean using clean, lint-free cloths.

b. Use extreme care when handling the seal faces. The lapped surfaces must be kept clean and free from scratches. Keep the seal faces in their protective wrapping or covered with a clean, dry, lint-free cloth until installed.

c. If the seal faces become soiled, they may be cleaned with water (or another solvent, if approved by the seal manufacturer in the instructions specific to the seal) and a clean, lint-free rag. Flush away any debris that might scratch the face before wiping the seal face clean. Scratched seal faces should not be used. The seal face may be lapped to remove minor scratches if lapping instructions with acceptance criteria specific to the seal, the required lapping equipment, and qualified personnel, are available. Otherwise, replace the part. If lapping cannot be done on site, it may be possible to return the part to the seal manufacturer for relapping and later use.

d. Ensure that the spring assembly is clean and free of debris that could impede its free axial travel.

503-5.3.9.2 Burrs and Sharp Edges. Carefully examine the pump shaft, shaft sleeve, and other parts that have tight clearances or that come in contact with elastomer parts during installation or operation. Remove any burrs or sharp edges that could interfere with the tight clearances or damage the elastomer parts.

503-5.3.9.3 O-Ring Fits. Check O-rings installed in grooves for a proper, snug fit. For O-rings which must be stretched over another part during installation, such as the pump shaft, ensure that sufficient time is provided for the O-ring to contract to a snug fit before installing the mating part.

503-5.3.9.4 Lubrication Of Secondary Seal. The elastomer secondary seal (e.g., O-ring or U-cup), which slides on the pump shaft or shaft sleeve in the assembly providing axial flexibility to the mechanical seal, should be lubricated. The surface against which the secondary seal slides should also be lightly lubricated in the narrow band where the secondary seal will slide. The lubricant used should only be that specified for the specific application. Some elastomer materials are adversely affected by inappropriate lubricants. For example, EPR (ethylene-propylene rubber) material swells when lubricated with petroleum-based substances.

CAUTION

Do not use petroleum jelly, TFE (tetrafluroethylene), or silicon grease on an elastomer driven seal. EPR must not be lubricated with any petroleum-based substance.

503-5.3.9.5 Lubrication Of Seal Faces. In general, the lapped seal faces do not require lubrication at assembly; they are lubricated by the liquid being sealed. Liquid lubricant should not be applied to the seal faces unless it is specifically called for in the manufacturer's instructions. Greases and other solids bearing lubricants should never be used. They will ruin the seal.

503-5.3.9.6 Seating Of Seal Faces. The seal face, in the element of the mechanical seal not containing the spring assembly, must be squarely seated without cocking to ensure proper seal performance and prevent secondary seal damage. Otherwise, the sliding secondary seal in the other element will be subject to a once-per-revolution sliding cycle. This can cause fretting of the elastomer seal and the seal sleeve/pump shaft. When installing the seal face, ensure that the seating surface is free of debris, burrs, and other upsets that could prevent the seal face from seating properly. If the seal face must be pressed into a recess with an O-ring sealing the outside diameter, ensure that the seal face is fully pressed against the seat during installation.

503-5.3.9.7 Alignment. Proper alignment is important to reliable operation of a mechanical seal. When installing mechanical seals, ensure that the pump shaft is straight and centered within the stuffing box within prescribed tolerances. Ensure that the close-tolerance fit, which locates the gland plate in the stuffing box, is free of debris and burrs and that the gland plate is properly seated when installed. Before coupling the pump to the drive motor, verify that the axial end-play in the motor is within tolerances. Ensure that the angular and radial alignment of the pump and its coupling assembly to the drive motor are within prescribed limits when the pump is reassembled. In particular, ensure that tapered couplings are properly assembled and that coupling faces are free of burrs and other debris.

503-5.3.9.8 Gland Plate Torquing. Ensure that the gland-plate bolting is properly torqued and not overtightened. Excessive tightening of the gland-plate bolting can lead to distortion of the gland plate and stationary seal face.

503-5.3.9.9 Filling And Venting. The pump and stuffing box should be filled with the pumped fluid and fully vented to remove all of the air from the pump. If some air remains in the pump, the seal faces may not be properly lubricated, producing overheating of the seal face, wear, and failure.

503-5.4 PACKED STUFFING BOXES

503-5.4.1 GENERAL. In a packed stuffing box, the seal between the moving shaft and the stationary cavity of the stuffing box is accomplished by forcing rings of packing between the two surfaces. A gland holds the packing in the stuffing box and is also used to control the amount of leakage along the shaft by tightening or loosening the gland nuts (see Figure 503-5-2). When a pump is designed to work on a suction lift, stuffing boxes are fitted with lantern rings or seal cages (usually located near the axial center of the stuffing box) to prevent air leakage into the stuffing box and to lubricate the packing. Sealing liquid is injected into the seal cage.

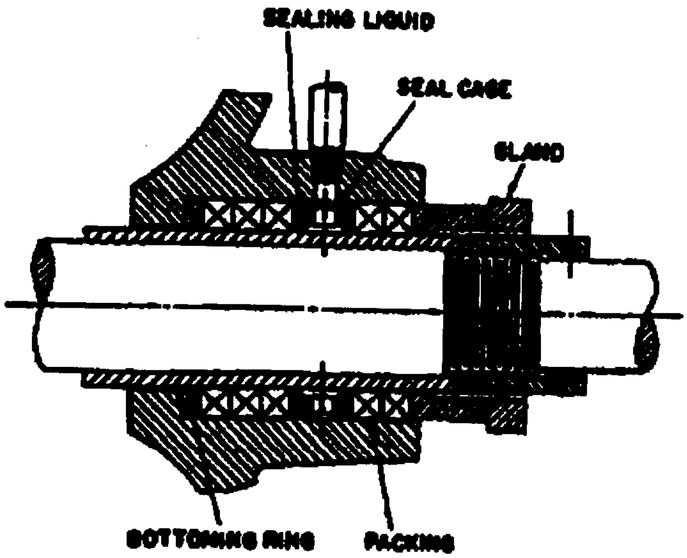


Figure 503-5-2. Packed Stuffing Box

503-5.4.2 SEAL LINE CONNECTIONS. When clean, cold water is pumped, the seal water line is usually connected to the pump casing near the discharge. To avoid excessive pressure in multistage pumps, the connection is to the first stage. An independent external liquid sealing supply is desirable under any of these conditions:

a. When suction lift is high.

b. When discharge pressure is low.

c. When the pump momentarily runs dry such as with a condensate pump.

d. When pumping hot water.

503-5.4.3 LEAKAGE AND REPLACEMENT CRITERIA. Leakage and replacement criteria for packed stuffing boxes and emergency backup stuffing boxes follow.

WARNING

Do not air-test a seal using the candle-flame method on a pump handling oil, gasoline, or other flammable liquid.

503-5.4.3.1 Non-Flammable Liquids. Take particular care to ensure that seal water piping is open and clear, allowing adequate flow of seal water to lubricate the packing. Otherwise, seal or stuffing box packing can wear rapidly from increased friction, causing shaft scoring. This in turn increases the clearance between the shaft and the packing, allowing air to be drawn in. When the pump is running, therefore, allow a little water to trickle out of the stuffing box. Test seal efficiency with a candle flame to see if air is being drawn into the pump. Even with the pump under a positive suction head, allow water to drip from the stuffing box to lubricate and cool the packing. Replace packing when the packing gland has been tightened to the point that it cannot control leakage. Partially replace packing only as a temporary or emergency action.

CAUTION

Do not draw packing glands too tight. Packing glands should be adjusted to allow a small amount of leakage to provide adequate packing lubrication and cooling.

503-5.4.3.2 Flammable Liquids. Leakage from flammable liquid pumps (for example fuel oil, JP-5, gasoline) should be maintained at 1 to 5 drops per minute. Monitor stuffing boxes carefully when starting the pump. At the first sign of overheating, stop the pump. The stuffing boxes should cool before restarting. When stuffing box leakage must be severely limited, as when pumping a flammable liquid, packing should be changed as frequently as required to maintain 1 to 5 drops per minute leakage and prevent shaft scoring.

503-5.4.4 INSTALLATION PROCEDURE FOR PACKING. The packing used in reactor plant pumps and surface ship boiler water main feed pumps shall accord with the pump technical manuals. All other water service pumps shall be packed with Teflon-impregnated packing in accordance with MIL-P-24377 and paragraphs 503-5.4.4.1 through 503-5.4.4.9 or as otherwise approved by NAVSEA except when the pump technical manual prohibits use of Teflon-impregnated packing. In the latter case, the procedure in the pump technical manual shall be followed. Any problems with installing, using, removing, and replacing Teflon-impregnated packing shall be directed to NAVSEA.

503-5.4.4.1 Remove all old packing from the stuffing box, being careful not to damage the shaft sleeve. Clean the stuffing box and examine the shaft sleeve for scoring. A deeply scored or rough shaft sleeve will result in short packing life and should be replaced.

503-5.4.4.2 If spool packing is used, cut rings making the ends square. Trim the ends so the butt clearances are 1/8 inch to 3/16 inch when the ring is wrapped around the shaft sleeve. Make sure the ends remain parallel. If time permits, soak the packing rings in water for several hours before installing.

503-5.4.4.3 Install the first ring of packing by inserting the butt joint into the stuffing box. Gradually press the rest of the ring with the fingers, starting at the butt joint and working around the circumference of the ring until the ring is evenly positioned in the stuffing box. The ring should fit snugly in the stuffing box without overlapping the ends. Use this technique to install all the packing rings.

503-5.4.4.4 Precision fit of packing ring OD and stuffing box ID should be obtained without forcing packing into the stuffing box. Trim the butts slightly to obtain a good fit without overlapping. Press this ring of packing into the stuffing box as far as it will go by installing gland halves and applying force until the gland contacts the stuffing box. Remove gland halves.

503-5.4.4.5 Install the remaining packing rings, and if required by the technical manual, install the lantern ring, using the same procedure as described in paragraphs 503-5.4.4.3 and 503-5.4.4.4. When packing is installed, stagger the joints 90 degrees. Refer to the individual equipment technical manual for the number of rings to install. If the last ring does not fit in the box but partially enters the box, do not force the ring into place; remove it.

503-5.4.4.6 Install gland halves, bolt together, and install the gland assembly washers and nuts. With the gland true to the shaft, finger-tighten the gland nuts until the gland contacts the top ring of the packing. If enough head is available, apply suction pressure to the pump and allow water to flow freely from the stuffing box for at least 30 minutes. This will provide time for the packing to absorb water, which will provide lubrication during startup and protection from burnout.

503-5.4.4.7 Start the unit. Run the pump for at least 1/2 hour with the gland leaking freely. Over time, gland leakage may decrease when the pump is rotating without tightening the packing. The procedures in paragraphs 503-5.4.4.8 through 503-5.4.4.17 are for inspection and adjustments after the shaft has been packed.

503-5.4.4.8 Tighten gland nuts in small increments, gradually reducing gland leakage to the amount specified in the technical manual. If none is specified, reduce to about 32 oz (1 quart)/min. Do not try to make this adjustment all at one time. Wait about 30 minutes between gland nut adjustments. To ensure that the gland does not cock and compresses the packing evenly, tighten nuts equally by counting the turns made. Use this procedure whenever nuts are adjusted. When gland leakage has been significantly reduced, it may be necessary to adjust gland nuts in small fractions of turns (or flats).

503-5.4.4.9 If one ring of packing was left out as allowed in paragraph 503-5.4.4.6, secure the pump and suction pressure. When packing has been compressed sufficiently to permit installation of the last ring, install the additional ring at this time.

503-5.4.4.10 Continue pump operation, gradually reducing the leakage further. Enough gland leakage must be maintained to cool the packing. One symptom of inadequate cooling is steam coming from the stuffing box. When the leakage is 20 to 30 oz/min, gland nut adjustment should not be more than 1 flat of the nut at a time. Below 20 oz/min, adjustment should be less than 1/2 flat of the nut. Allow about 30 minutes between adjustments to stabilize the packing. Sometimes, when small adjustments are made, the gland nuts can be turned without a noticeable change in leakage rate. Do not reduce gland leakage too much, since loosening the gland nuts does not always result in increased gland leakage.

503-5.4.4.11 If leakage decreases too rapidly, slack off gland nuts to increase leakage. If the stuffing box heats up, indicating that the packing is overheating, secure the pump. Allow the stuffing box to cool, loosen the gland nuts about 1/2 turn, and restart the unit. This may restore gland leakage to the minimum required.

503-5.4.4.12 The minimum gland leakage rate obtained will depend on four factors: the speed of the motor, the diameter of the shaft sleeve, the pressure the packing seals against, and the temperature of the water. As each of these factors increases, the minimum amount of gland leakage that should be obtained to prevent burning the packing increases. For example, a submarine main feed pump with a speed of 3,600 r/min, shaft sleeve diameter of 3-3/4 inches, a packing sealing pressure of 100 lb/in^2 g, and a water temperature of 65.6° C (150° F) requires a minimum gland leakage of 8 oz/min (this is a stream about the size of a pencil). On the other hand, another pump pumping water of about the same temperature but with a speed of 1,800 r/min, a shaft sleeve diameter of 1-1/8 inch and a packing sealing pressure of 25 lb/in^2 g can obtain a gland leakage rate of 0.1 oz/min. For pumps with variable speeds, suction temperatures, or packing sealing pressures, the minimum gland leakage rate should be adjusted to a rate acceptable for all operating conditions.

503-5.4.4.13 Once the packing has been broken-in, limit the amount of leakage to what the system can tolerate or to an amount that will not undesirably affect the equipment or surrounding spaces. Gland leakage, however, should always be less than 32 oz/min.

503-5.4.4.14 Periodically monitor the packing leakage rate. Adjust the gland nut only when gland leakage exceeds acceptable rates. When changing gland leakage, do not make large or rapid adjustments of gland nuts.

503-5.4.4.15 If leakage is cut off completely and smoke comes from the stuffing box, secure the pump immediately, remove the packing, and repack with a new set of rings. If the packing cannot be replaced immediately, one ring of packing can be temporarily installed next to the gland to limit the leakage until the entire set can be replaced. Replace the full set of packing rings at the first opportunity.

503-5.4.4.16 Replace the packing when adjusting the gland nuts no longer controls gland leakage. If time permits, replace all the packing rings. In an emergency, if leakage is excessive:

1. Secure the unit.
2. Remove the gland.
3. Install the new packing ring and reinstall the gland, if the one ring of packing has been compressed enough to allow installation of an additional ring while leaving room to seat the gland.
4. Start the unit.

503-5.4.4.17 The leakage rate at this time may vary considerably, depending on the condition of the packing rings. Replace the full set of packing rings at the first opportunity.

SECTION 6.

ALIGNMENT

503-6.1 WHAT IS ALIGNMENT?

503-6.1.1 Alignment is the process of adjusting two or more machines that are coupled together so their shaft centerlines form one continuous straight line. The term shaft-to-shaft alignment should be used instead of coupling alignment. Even though the couplings are aligned properly, the shaft centerlines may not form one continuous straight line. This depends on whether the couplings were bored straight and true and were machined perfectly about their rim and face. The goal is to align the shaft centerlines, not the couplings. An alignment check is the process of measuring the offset and angularity of one shaft centerline in relation to the other shaft centerline.

503-6.2 WHY ALIGN EQUIPMENT?

503-6.2.1 The pump and driver must be properly aligned to eliminate undue mechanical stresses on the shafts, bearings, coupling, and mechanical seals. It is important that the centerlines of the two shafts form one continuous straight line that does not exceed the maximum tolerances recommended in the Technical Manual or in the Alignment Manual, NAVSEA S6226-JX-MMA-010. Alignment should be checked to determine whether the shafts are within the specified tolerance of offset and angularity. Alignment checks are required by PMS at regular intervals. If the equipment experiences increased vibration or failure of bearings, couplings, or mechanical seals, an alignment check should be performed using the PMS procedures. Alignment should also be performed when new or overhauled equipment is installed or when the equipment alignment maximum tolerances have been exceeded. Consult the appropriate technical manual or NAVSEA S6226-JX-MMA-010 for maximum tolerances.

503-6.3 IMPORTANCE OF PROPER PIPING ALIGNMENT

503-6.3.1 Proper suction and discharge piping alignment is also critical to the alignment of the pump and driver. Misalignment of suction and discharge piping connections can cause pump and driver misalignment. Piping flanges and fastener holes must be aligned so that no external force is required to attach the flanges. Chain falls, pry bars, jacks, or wedges shall not be used to position piping. Proper piping alignment is achieved when correct sized flange fasteners fit through the fastener holes without applying external force to the piping. Ideally, flanges should be brought together freely with minimal gap between flange faces. This gap should be equal over the entire periphery of the flange bolt (fastener) circle. Prior to connecting suction and discharge piping, set up dial indicators on the coupling hubs. When connecting the pipe flanges, observe the dial indicators for movement or strain imposed on the equipment by the piping. Eliminate any strain imposed. Minor piping adjustments can be accomplished by modifying and adjusting the pipe hangers. Major piping adjustments will require cutting and refitting the piping or relocating the hanger.

503-6.4 TERMINOLOGY

503-6.4.1 The following terminology applies to alignment:

a. Alignment - The process of adjusting two machines that are coupled together so that their shaft centerlines form one continuous straight line.

b. Angularity - The angle that one shaft centerline makes in relation to the other shaft centerline in both the horizontal and vertical planes. Angularity is expressed as a slope of so many thousandths of an inch per inch, rather than an angle of degrees.

c. Offset - The distance between two shaft centerlines in the horizontal and vertical planes. Offset is expressed in thousandths of an inch.

d. Alignment Computer - A device that leads the user through the alignment process by prompting the user to measure and enter the dial indicator readings required for proper alignment. An alignment computer can be used for the indicator reverse and rim and face methods, and will provide the user with the number of shims necessary for proper alignment.

e. Machine To Be Shimmed (MTBS) - When aligning two machines, adjustments will usually be done on only one of the machines. The other machine is usually difficult to adjust because of its size, physical attachment to other objects (such as a pump that is attached to its piping), or its anchorage system (some machines are permanently grouted in place). In most applications (gear reducer-motor, pump-motor, pump-turbine, etc.), the driver (the motor or the turbine) will be the machine that is adjusted. In some applications, however, such as the main fuel oil pump on a gas turbine, the driven machine will be adjusted. To avoid confusion, the term MACHINE TO BE SHIMMED will be used to describe the machine that is to be adjusted or shimmed.

f. Stationary Machine - The machine that will not be adjusted (the pump, gear reducer, etc. in most cases).

g. Vertical Misalignment - When the MTBS must be adjusted vertically with shims to bring it into its correct position.

h. Horizontal Misalignment - When the MTBS must be adjusted horizontally to bring it into its correct position. (Shims are not used to correct horizontal misalignment.)

i. Rim Readings - Readings obtained as the shafts are rotated and the centerline of the dial indicator stem is set at a 90-degree angle to the shaft centerline.

j. Face Readings - Readings obtained as the shafts are rotated and the centerline of the dial indicator stem is set parallel to the shaft centerline.

k. Indicator Sag - The bending of the dial indicator mounting hardware that occurs, due to gravity, when the dial indicator is rotated from the top position to the bottom position. In many cases, this bending may be large enough to cause a significant error in the dial indicator readings. This sag must be compensated for when the mechanic sets the indicator in the top position.

l. Zero - The process of setting the dial indicator to zero when it is in the top position. Although this procedure is normally used to obtain alignment readings, it is not recommended. Set the indicator to a value which compensates for indicator sag when it is in the top position and obtain a reading at the 180-degree position. Next, reset the indicator to zero in the 90-degree position and obtain a horizontal reading at the 270-degree position.

m. Soft Foot - A condition that exists when the bottom of all four feet of a machine are not on the same plane. This condition can be compared to a chair that has one short leg.

n. Front Feet - The inboard (close to the coupling) feet of the MTBS.

o. Back Feet - The outboard (away from the coupling) feet of the MTBS.

p. Hold-down Fasteners - The fasteners used to secure each foot of the machine to the machine base.

q. Jacking Fasteners - Fasteners positioned horizontally on the machine base located at each machine foot. They are used to adjust the horizontal position of the machine. Not all machines have jacking fasteners.

503-6.5 STEPS NECESSARY TO ACHIEVE A SATISFACTORY ALIGNMENT

503-6.5.1 The following is a list of steps necessary to achieve a satisfactory alignment:

NOTE

When performing an alignment check, only steps 1, 6, 8, and 10 apply.

1. If equipment is in service, tag out power source and disconnect suction and discharge piping.
2. If new or overhauled equipment is being installed, ensure that machine base and bottom of machine feet are clean and free of rust and burrs. Clean if necessary.
3. Use only clean shims of the approved material (304 stainless steel) and remove any burrs. Remove all existing shims and inspect them for adequacy. Do not use laminated shims or brass shims. Shims, shim kits, and related NSNs are shown on NAVSEA dwg 803-68997419.
4. Check for soft-foot and correct if necessary before starting alignment as described in paragraph 503-6.6.
5. Use a consistent tightening procedure on the hold-down fasteners as described in paragraph 503-6.7.

6. Check and compensate for indicator sag (horizontal units only) before taking alignment readings as described in paragraph 503-6.8.
7. If new or overhauled equipment is being installed or misalignment is too great to obtain dial indicator readings, rough align using the straight edge and thickness gauge method described in paragraph 503-6.10.2.3.
8. Use an approved alignment method in accordance with paragraph 503-6.10.
9. Ensure that piping is properly aligned, then connect suction and discharge piping.
10. Perform hot alignment check for turbine driven pumps. (Also perform for some motor driven pumps to identify and compensate for the thermal growth of the equipment as described in paragraph 503-6.11.)
11. Install dowel pins to ensure that new alignment is maintained as described in paragraph 503-6.12.

503-6.6 SOFT-FOOT CHECK

503-6.6.1 To correct for soft-foot, add shims under the soft-foot. This condition should be identified and corrected as the first step in an alignment procedure. To correct for soft-foot, proceed as follows:

NOTE

All other feet must remain secured to the base when a foot is being checked for soft-foot. For equipment already installed, perform steps 5 through 9 only.

1. Ensure that machine base, feet, and shims are clean and free of rust and burrs.
2. Set the machine on the base. Do not tighten the hold-down fasteners.
3. Check the gap between machine base and each machine foot with a feeler gauge. Add shims to compensate for the gap.
4. Tighten all hold-down fasteners in accordance with paragraph 503-6.7.
5. Mount a dial indicator to the machine base. Locate the centerline of the indicator stem vertically above the foot to be checked. Set indicator to zero.
6. Loosen the hold-down fastener on the foot being checked only. Watch the dial indicator for foot movement.
7. If the foot rises as the hold-down fastener is loosened, add shim stock with a thickness equal to the dial indicator deflection.
8. Tighten the hold-down fastener. Repeat steps 6 and 7 to ensure soft-foot has been corrected.
9. Repeat steps 5 through 8 for each foot of the machine.

503-6.7 TIGHTENING OF HOLDDOWN FASTENERS

503-6.7.1 Proper tightening of hold-down fasteners is important. It ensures that any unequal stresses, which may cause the machine to move during the tightening procedure, will remain the same during the entire alignment process. Use the following procedure for tightening hold-down fasteners:

1. After soft-foot has been eliminated, loosen all hold-down fasteners.

2. Mark each foot of the machine with a number. The number should be in the sequence that will be used for tightening during the alignment (use an X pattern).
3. Always tighten fasteners in the same sequence.
4. Always loosen fasteners in the opposite sequence.
5. Always use a torque wrench and tighten all fasteners with the same amount of torque.

503-6.8 INDICATOR SAG CHECK

503-6.8.1 Indicator sag can cause significant errors in the rim readings used to determine vertical misalignment of horizontal units. To ensure accurate readings, always measure the amount of indicator sag in the mounting hardware first. Also compensate for the sag when taking readings. Proceed as follows:

1. Mount the dial indicator on a piece of pipe using the same hardware and exact horizontal span that will be used during alignment.
2. Hold the pipe horizontally with the dial indicator in the top position.
3. Set the dial indicator to zero.
4. Rotate the pipe about its centerline until the dial indicator is in the bottom position.
5. Read the dial indicator in the bottom position to obtain the amount of indicator sag. It will be a negative number, such as -0.012 inch.
6. Install the brackets and dial indicators on the machines exactly as they were installed on the pipe above.
7. Set the dial indicator in the top position to the opposite value (positive number +0.012 inch) of the sag determined in step 5.

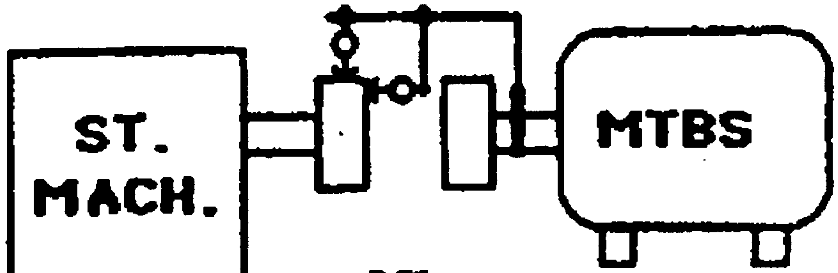
503-6.9 ALIGNMENT ACCURACY

503-6.9.1 Alignment accuracy not only depends on the precision of the measuring instruments, but on how the instruments are used. For example: when a dial indicator, which is considered a precision instrument, is used to measure offset alignment while rotating only one shaft, the readings are no longer precise offset alignment readings. Coupling irregularities have now been introduced into the readings. To obtain truly precise alignment readings using a dial indicator, both shafts must be rotated.

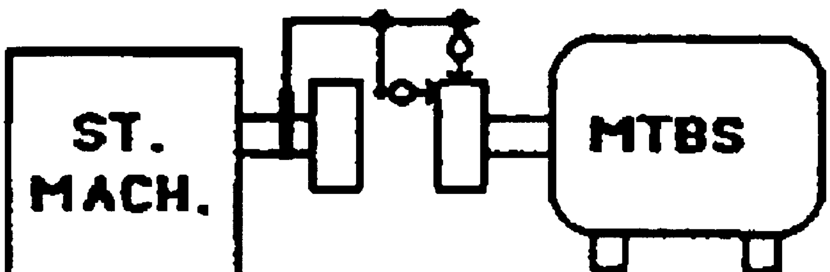
503-6.10 APPROVED ALIGNMENT METHODS

503-6.10.1 GENERAL. This section describes the NAVSEA approved alignment methods. The alignment methods described in paragraph 503-6.10.2 will give accurate results. They can be accomplished using a laser alignment kit, dial indicators, and an alignment computer, or dial indicators and hand calculations.

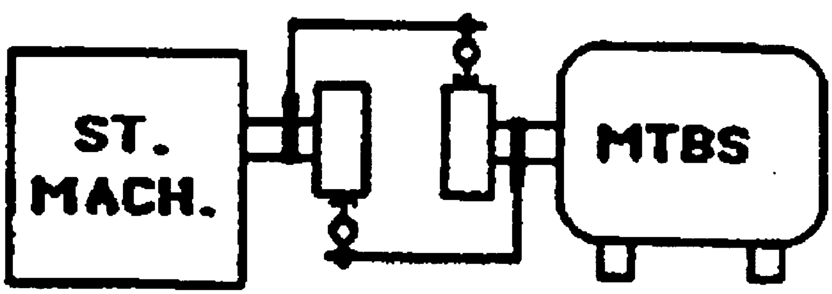
503-6.10.2 ALIGNMENT METHODS. The following alignment methods are listed in order of precedence and described in paragraphs 503-6.10.2.1 and 503-6.10.2.2. Refer to Figure 503-6-1 for dial indicator mounting arrangements for the alignment methods.



M1



M2



M3

Figure 503-6-1. Dial Indicator Mounting for Indicator Reverse Method (M3) and Rim and Face Methods (M1 and M2)

503-6.10.2.1 Indicator Reverse Method. The indicator reverse method requires that one rim reading be taken on each coupling and that both driver (motor, turbine, etc.) and pump shafts be rotated simultaneously. One reading is taken with a dial indicator mounted on the driver shaft with the indicator sensing arm in contact with the pump coupling rim. Another reading is taken with a dial indicator mounted to the pump shaft, with the indicator sensing arm in contact with the driver coupling rim. If two dial indicators are available, these readings may be taken at the same time. If only one dial indicator is available, the indicator reverse method can still be used; however, each reading must be taken separately. In most cases, when using the indicator reverse method, the flexible coupling does not have to be disassembled. Refer to the alignment manual, S6226-JX-MMA-010, for detailed procedures using the indicator reverse method to align horizontal pump units. For vertical pump units, the indicator reverse method can be used to check alignment only. To perform a permanent vertical pump unit alignment, the rim and face method must be used.

503-6.10.2.2 Rim And Face Method. The rim and face method can be done either of the following ways for horizontal pump units (Figure 503-6-1):

a. One rim reading and one face reading taken on the stationary machine with the dial indicator mounting brackets attached to the MTBS. Both shafts must be rotated simultaneously to check proper shaft alignment.

b. One rim reading and one face reading taken on the MTBS with the dial indicator mounting brackets attached to the stationary machine. Both shafts must be rotated simultaneously to check proper shaft alignment.

503-6.10.2.2.1 For vertical pump unit alignment, it is necessary to use both rim and face readings, though not simultaneously. First, angular misalignment must be corrected by shimming the motor. Second, the offset misalignment must be corrected by moving the motor flange on the base plate.

503-6.10.2.3 Straight Edge And Thickness Gauge Method. The straight edge and thickness gauge method is an approximate method of checking alignment. It should be used to get the equipment close on an initial setup or as a last resort for alignment. This method is not an accurate alignment. It should be used only when precision instruments are not available. The following procedure should be used for the straight edge and thickness gauge method to rough align equipment being installed (Figure 503-6-2):

1. Ensure that machine base and bottom of machine feet are clean and free of rust and burrs. Clean if necessary.

2. Use only clean shims of the approved material (304 stainless steel) and remove any burrs. Do not use laminated shims or brass shims.

3. Check for proper coupling end gap in accordance with the applicable technical manual.

4. Check angular alignment by inserting thickness gauge between the coupling faces at 90-degree intervals. If any of the four readings differ by 0.002 inch or more, adjust the angular alignment by shimming or moving the motor. Recheck angular alignment after each movement.

5. Check offset alignment by placing a straight edge across both coupling rims at 90-degree intervals. Adjust or shim the motor until the straight edge rests evenly on the coupling rim at all positions.

6. After all adjustments have been completed, recheck both angular and offset alignment.

7. Connect the suction and discharge piping. Recheck angular and offset alignment.

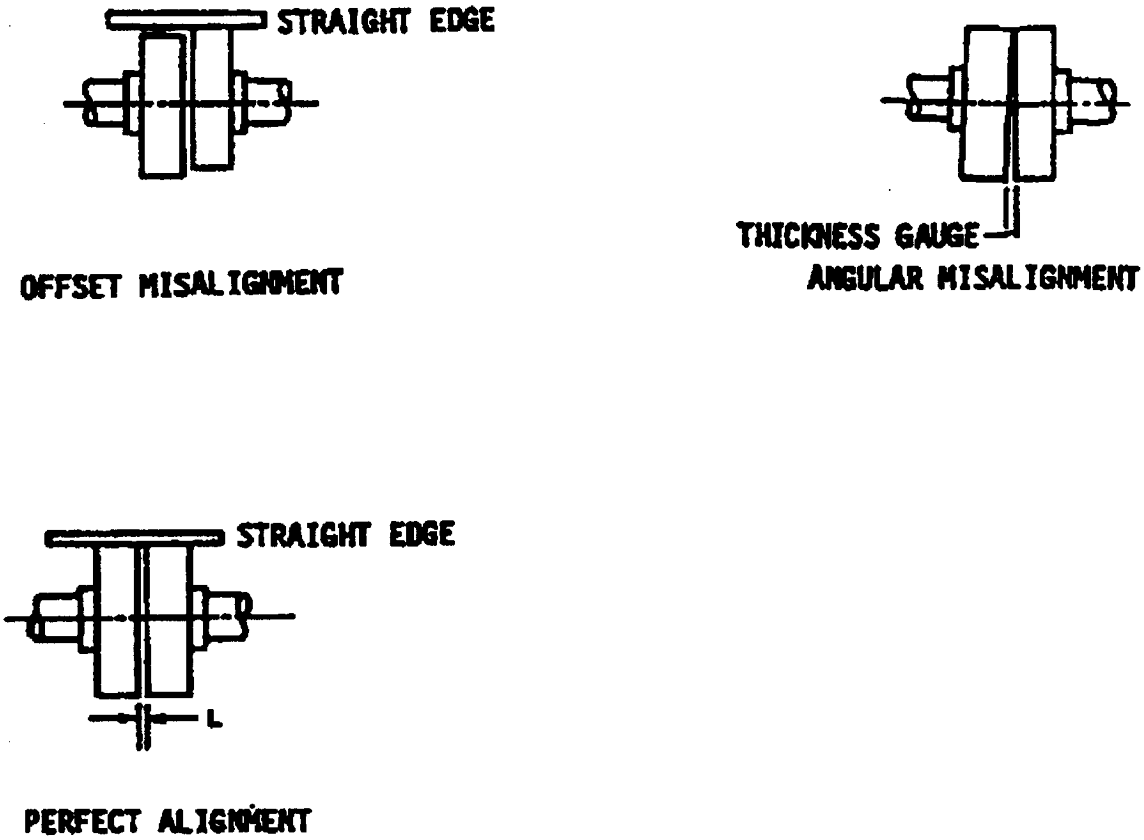


Figure 503-6-2. Straight Edge and Thickness Gauge Method

503-6.11 HOT ALIGNMENT CHECK

503-6.11.1 When a machine, especially a turbine, goes from non-operating to operating condition a temperature rise usually occurs, causing the metal to expand. The expansion of metal components causes the shaft to rise. This can significantly influence the equipment alignment. Therefore, when aligning equipment such as a steam turbine, extreme care must be taken to account for thermal growth. Align the equipment in accordance with the equipment technical manual which should account for thermal growth. When equipment technical manuals are not available, align the equipment in the cold condition, run it up to operating temperature (about 4 hours), then perform a hot alignment check. The accuracy of a hot alignment check depends on how soon after shutdown the dial indicator readings are taken. The use of shaft-mounted brackets is recommended. They should be assembled to the fullest extent possible prior to equipment shutdown so that readings can be taken before the equipment cools. Readings should be taken within 15 minutes of shutdown. The indicator reverse method should be used for the hot alignment check because the flexible coupling usually does not have to be disassembled to obtain the required rim readings. Refer to the alignment manual, NAVSEA S6225-JX-MMA-010, for the detailed procedure on taking hot alignment readings and making appropriate adjustments. If the rim readings are entered into the alignment computer, it will give the correct thickness of shims required to align the equipment for normal operating temperature.

503-6.12 DOWEL PIN PLACEMENT

503-6.12.1 It is important to install new tapered dowel pins of the approved material (304 stainless steel) that pass through the equipment mounting feet and into the baseplate. Dowel pins have a snug fit as opposed to the anchor fasteners which are usually in slotted holes. Dowel pins will positively locate the equipment and prevent shifting and misalignment. Dowel pins should be installed in the front feet (feet closest to the coupling) of each unit. Use the following procedure to install dowel pins:

1. Use tapered dowel pins with a 1/4 inch per foot taper and of sufficient length to extend completely through the equipment foot and baseplate.

2. Ream tapered holes (1/4 inch per foot taper) through the equipment foot and the baseplate.

3. Insert tapered dowel pins in holes and secure pins.

503-6.13 CLOSE-COUPLED PUMP ALIGNMENT

503-6.13.1 Close-coupled pumps have one common shaft for the pump and motor. When a close-coupled pump has been overhauled, dial indicator readings shall be taken during pump reassembly to ensure that the shaft is straight and that the impeller and stationary parts are perpendicular and concentric.

503-6.13.2 Normally, the limit of acceptable shaft runout is 0.002-inch TIR unless otherwise specified by the manufacturers' technical manual. When indicating from the shaft to the flange face or the spigot rim or rabbet of the housing or motor bracket, the runout should remain within 0.002 inch. The motor bracket is fastened to the motor, and the pump casing is fastened to the motor bracket.

503-6.13.3 Because the casing is assembled with one machined surface against another, errors in the end face are cumulative. These errors could result in a varying centerline which deviates from the shaft centerline. In a practical sense, the impeller wearing rings and the casing wearing rings may not be concentric. This causes excessive clearance on one side and rubbing on the other. This condition is aggravated if the casing wearing ring is slightly out of round. In the final assembly it is important to ensure that the radial clearances between the wearing rings are within tolerance and that the pump impeller is located with acceptable end clearance.

503-6.13.4 The meanings of various alignment terms are as illustrated in Figure 503-6-3.

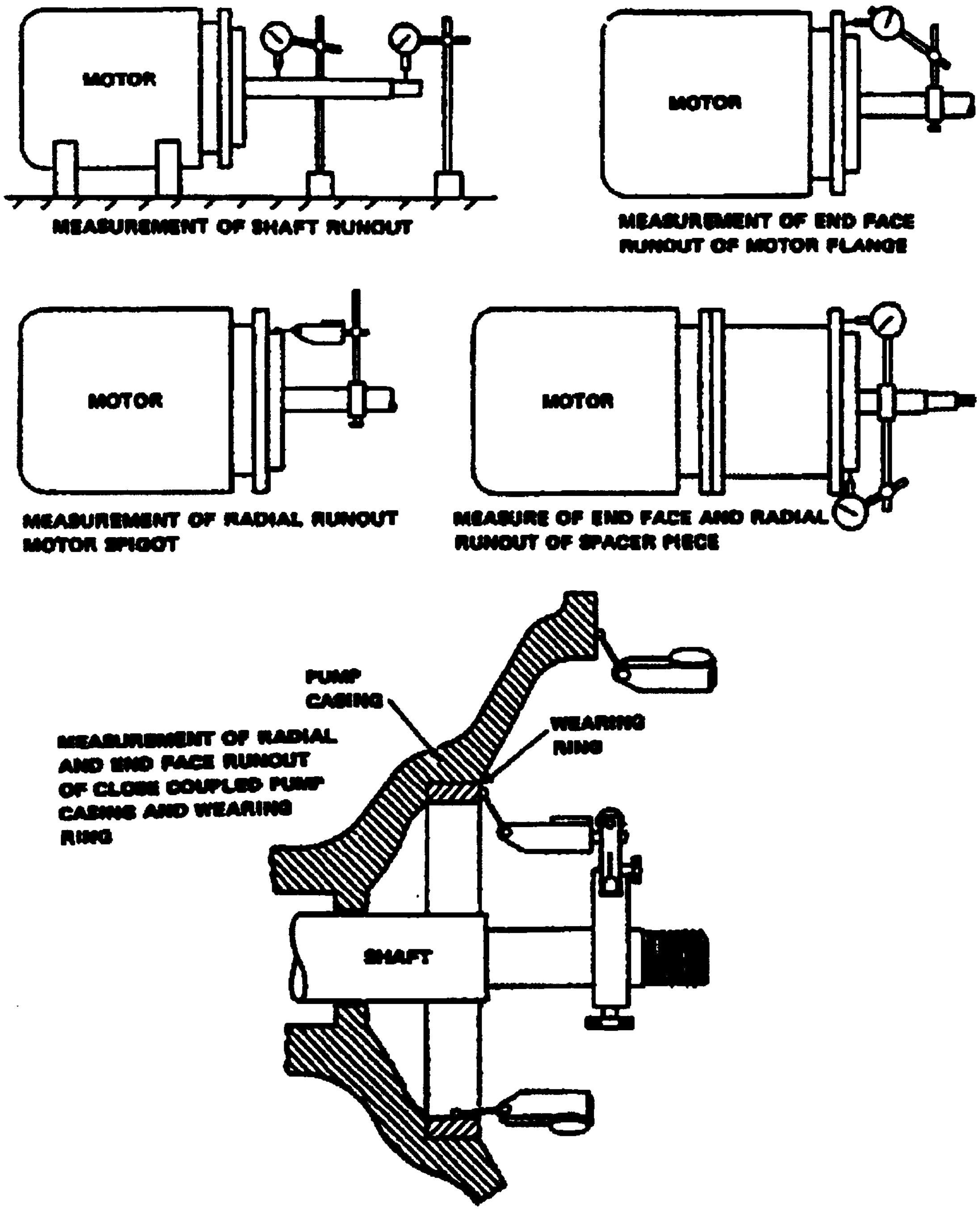


Figure 503-6-3. Methods for Checking Close-Coupled Pump Radial and End-Face Runout

503-6.13.5 Procedures that shall be used in checking or performing close-coupled pump alignment are given in paragraphs 503-6.13.6 through 503-6.13.13.

503-6.13.6 Check shaft runout. Mount the dial indicator firmly to the motor if practical. Position the sensing arm against the shaft next to the motor bell housing. Zero the indicator. Observe the indicator and rotate the shaft one turn. Turn the shaft to the highest indicated reading. Zero the indicator again. Rotate the shaft one turn. Record the maximum deviation. Runout should be within 0.002-inch TIR or within the manufacturers' recommended tolerances. If outside of these tolerances, the runout must be corrected before proceeding. Excessive shaft runout next to the motor indicates the problem is in the shaft or bearings. Shift the indicator sensing arm to the pump end of the shaft. Check shaft runout. If shaft runout next to the motor is acceptable but pump end runout is excessive, the shaft is bent or damaged. Repair it before proceeding.

503-6.13.7 Check motor flange end face runout and motor spigot radial runout (see Figure 503-6-3). Mount the dial indicator firmly to the pump shaft. Position the sensing arm against the face of the motor flange. Zero the indicator. Observe the indicator and rotate the shaft one turn. The pump flange face should be perpendicular to the axis within 0.002 inch. If there is excessive runout, correct the cause before proceeding. Position the indicator sensing arm on the motor spigot as illustrated in Figure 503-6-3. Zero the indicator. Observe the indicator and rotate the shaft one turn. The motor spigot should be concentric within 0.002 inch. If there is excessive runout, the cause may be burrs or a damaged spigot.

503-6.13.8 Install the spacer piece. Check the end face and radial runout (see Figure 503-6-3). Mount the dial indicator firmly to the pump shaft. Position the sensing arm against the end face. Zero the indicator. Observe the indicator and rotate the shaft one turn. The spacer face should be perpendicular to the axis within 0.002 inch. If there is excessive runout, the cause may be an incorrectly installed spacer piece or burrs on the mating surfaces. Correct it before proceeding.

503-6.13.9 Install the close-coupled pump casing. Check the radial and end face runout of the casing and wearing ring (if installed). Mount the dial indicator firmly to the pump shaft. Position the sensing arm against the casing end face as illustrated in Figure 503-6-3. Zero the indicator. Observe the indicator and rotate the shaft one turn. The casing face should be perpendicular to the axis within 0.002 inch. If there is excessive runout, the cause may be an incorrectly installed casing or burrs on the mating surfaces. Shift the sensing arm to the end face of the wearing ring. Zero the indicator. Check the wearing ring runout. The wearing ring face should be perpendicular to the axis. Acceptable casing face runout with excessive wearing ring face end runout means the wearing ring is seated improperly or is damaged. Shift the sensing arm to the wearing ring inner surface. Zero the indicator. Check the radial runout. The wearing ring should be concentric within 0.002 inch. If the radial runout is excessive, the cause may be incorrectly installed or out-of-round wearing rings. Correct it before proceeding.

503-6.13.10 Install the impeller. Check the impeller radial and face runout. Mount a dial indicator firmly to the pump casing. Position the sensing arm against the impeller shoulder or hub face. Observe the indicator. Rotate the pump shaft one turn. The impeller should be perpendicular to the axis within 0.002 inch. If there is excessive runout, the cause may be an improperly installed impeller or flaws on the impeller shaft seat and shoulder. Shift the indicator sensing arm to a parallel surface on the impeller (wearing ring surface, if installed). Zero the indicator. Check the radial runout. The impeller should be concentric within 0.002 inch. If there is excessive runout, the impeller may not be centered on the shaft, a burr is on the indicating surface, or the impeller outside diameter (OD) is not machined properly. Correct the excessive runout before proceeding. If the impeller is remachined, reestablish dynamic balance.

503-6.13.11 Set the end plate in place. Before inserting the hold-down fasteners, mount a dial indicator firmly to a motor, if practical. Position the indicator sensing arm against the top of the end plate. Zero the indicator. Check the clearance between the end plate shoulder and the pump casing by moving (or trying to move) the end plate up and down. Record the reading. If there is any clearance, hold the end plate in the center while tightening the hold-down fasteners. For example, if the indicated clearance is 0.005 inch, move the end plate a maximum of 0.0025 inch to center the end plate on the pump casing.

503-6.13.12 If the close-coupled pump has supporting pads on the motor and pump end, install and tighten the motor hold-down fasteners. Mount a dial indicator firmly on the motor. Position the sensing arm against the top of the pump casing. Zero the indicator. Measure the clearance between the pump pads and the bedplate by inserting a thickness gage. If there is a gap, shim before inserting bolts. When shimming to correct the gap, add 0.002 to 0.003 inch to the indicated reading. For example, if the indicated gap reading was 0.005 inch, the shim thickness should be 0.007 inch to allow for compression when hold-down fasteners are tightened. While tightening the pump pad hold-down fasteners, observe the dial indication to ensure that tightening the bolts does not misalign the pump.

503-6.13.13 Insert bolts for suction and discharge piping in the respective pump flanges. Before tightening bolts, mount a dial indicator firmly on the motor. Position the sensing arm against the top of the pump casing. Zero the indicator. The piping must be sufficiently aligned to allow assembly of the flange joints by hand without having to use excessive force. Observe the indicator while tightening the bolts to ensure that the piping is not pulling the pumps out of alignment. If there is indication that the suction and discharge piping are exerting excessive forces on the pump flanges, correct by modifying piping alignment.

REAR SECTION

NOTE

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